

SCHEDULING GUIDE FOR PROGRAM MANAGERS

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FOREWORD

This guide provides an introduction to scheduling intended for use by government program managers and industry program of project managers and their respective staffs. It is the third version of a 1986 publication prepared by Mr. David D. Acker, Mr. J. Stanley Baumgartner, and Mr. Michael B. Patterson. A second version, published in 1994, was prepared by Mr. William W. Bahnmaier and Mr. Paul T. McMahon.

This version addresses many of the topics contained in their earlier versions, especially those relating to the different types of scheduling techniques. The major difference between this and the previous versions is the treatment of scheduling as part of the acquisition process and the overall program management effort, particularly as it relates to the planning and control functions of program management. Scheduling is discussed in the context of the development of integrated master plans and schedules, the risk management process, and earned value management.

This guide is not intended as a detailed treatment of scheduling techniques. Instead, it is more of a primer on the subject, addressing the importance of scheduling and the application of basic scheduling techniques. It is a compilation of information from various sources, and hopefully will serve as a starting point for those who desire to delve deeper into the various scheduling techniques.

The proliferation of microcomputers has greatly enhanced the capability of managers at all levels to develop and analyze schedules. Chapter 9 provides an overview of the types of automated tools available and information on desirable features of scheduling software applications.

This document reflects the efforts of many people. Mr. William W. Bahnmaier, Mr. Paul T. McMahon, Lt Col. David Bachman, USAF, and Mr. John Kelley of the DAU/DSMC faculty provided invaluable guidance and advice. Mr. Gregory T. Caruth of the DAU/DSMC Press was very helpful in the composition of the guide. Frances M. Battle, provided desktop publishing skills. Mr. Van Kinney, Ms. Joni Forman and Mr. Tom Parry of the OSD Acquisition, Resources and Analysis staff provided comments on the draft and overall support for the project. Special recognition also goes to the Institute for Defense Analysis team of Mr. Lou Simpleman, Mr. Jim Lloyd, Mr. George Tolis, Ms. Patti Phillips, Ms. Tina Higgins, and Ms. Yolanda Prescott, who wrote, edited, and prepared the major portions of the text.

Norman A. McDaniel
Chair
Program Management and Leadership
Department

William W. Bahnmaier
Editor
Program Management and Leadership
Department

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1

INTRODUCTION

1.1 OVERVIEW

In its simplest form, a schedule is a listing of activities and events organized by time. In its more complex form, the process examines all program activities and their relationships to each other in terms of realistic constraints of time, funds, and people, i.e., resources. In program management practice, the schedule is a powerful planning, control, and communications tool that, when properly executed, supports time and cost estimates, opens communications among personnel involved in program activities, and establishes a commitment to program activities.

A key aspect of program management planning, scheduling is integral to a program's acquisition strategy and to risk management, financial, and technical management plans. In addition, scheduling is an important element of the other management functions: organizing, staffing, controlling, and leading. For example, controlling is performed to keep abreast of program execution. To achieve this goal, it is necessary to know whether the program is behind, on, or ahead of schedule, and what adjustments are necessary to keep the program on schedule once it's back on track.

Why do Program Managers (PMs) schedule? The simple answer is they need a road map for all program players. In reality, scheduling can accomplish far more than providing a list of activities and times.

Effective scheduling supports the following key program management activities:

- Provides the basis for effective communications within the government team and with contractors,
- Identifies a baseline for program status monitoring, reporting, and program control,
- Facilitates management, and
- Provides the basis for resource analysis and leveling, exploration of alternatives, and cost/time tradeoff studies.

On the other hand, poor scheduling can adversely impact a program in a number of areas. Haphazard schedules make it difficult, at best, to determine a realistic completion date and to efficiently allocate resources to the entire program. This creates financial problems—escalation of costs, increased support costs, delayed return on investment, funding cuts, or program termination.

Since scheduling is a powerful planning, control, and communications tool available for program management, PMs must have a good working knowledge of scheduling practices and applications (such as Gantt, milestone, and network schedules) in order to achieve program goals. PMs will not always have to construct detailed schedules, but they must be able to understand and analyze schedules created by

others (e.g., contractors) to successfully manage a program. Since scheduling is an intrinsic and indispensable element of the management process, it is treated within the context of program management.

1.2 PURPOSE OF THIS GUIDE

This guide is an introduction to scheduling. It is meant for people who already have some experience in program management and those who seek to learn more about the subject. It is not a detailed treatment of the subject, but instead, explains how scheduling fits into the overall program management effort and how to accomplish schedule planning. It also illustrates different scheduling concepts and techniques and how they can be applied and analyzed to manage effectively. Finally, it is intended as a road map to other useful and more comprehensive documents and texts on the subjects of project management, planning, and scheduling that are available in the literature.

1.3 GUIDE CONTENT

In order to provide a suitable context for the topic of scheduling, Chapter 2 provides an overview of both program management and the acquisition process and the role scheduling plays in each.

Chapter 3 expands on the role of scheduling in program management and addresses the following topics: work breakdown structure, integrated master plans and schedules, and earned value management. It concludes with a discussion of schedule preparation and schedule risk.

Chapter 4 introduces the topic of scheduling techniques with a general discussion of

the various types of schedules and how and why they evolved. This chapter is a precursor for Chapters 5, 6, and 7, which present a more detailed discussion of the key schedule types. These chapters focus on Gantt and milestone schedules, network schedules, and production schedules.

Chapter 8 introduces the concept of time management as it relates to the program and to the PM. Chapter 9 presents the subject of automated project planning tools and summarizes some of the desirable features of currently available software products. In addition to an overview describing the types of automated tools available, this chapter provides some suggestions on how to find and evaluate the latest products. The chapter concludes with a summary of information sources that will be useful for further inquiry.

1.4 OTHER SOURCES OF DATA

As previously noted, this guide is intended as a primer. There is a considerable body of literature on the subject of scheduling. Much of it is of an academic nature not specifically keyed to defense acquisition. A number of these texts are listed in the Bibliography Appendix of this guide. Additionally, an enormous amount of relevant information can be secured by searching the web using some of the popular search engines.

Of particular use to PMs is the *Defense Acquisition Deskbook*, available on the Internet (<http://www.deskbook.osd.mil>). The *Deskbook* includes a database containing mandatory and discretionary policy documents, Department of Defense and component discretionary practices, software tools and descriptions, front-line wisdom and advice, and sample formats.

2

PROGRAM MANAGEMENT AND THE ACQUISITION PROCESS

2.1 PROGRAM MANAGEMENT OVERVIEW

The Department of Defense (DoD) considers program management to consist of the tasks and activities that must be done in order to design, develop, field, and support a weapons system. DoD directives describe an Acquisition Program as: “A directed, funded effort that is designed to provide a new, improved, or continuing weapons system or automated information system (AIS) capability in response to a validated operational need.”¹ DoD considers the “program” to include the elements of the acquisition process, such as the planning, programming, and budgeting process, and the design, development, and production of the system. Practically speaking, a DoD program consists of a combination of organizational resources, assembled to create a weapons system to meet a specific operational requirement.

Four key considerations typically involved in a program are:

- Cost to produce the system,
- Time required to complete the effort,
- Capability/technical performance required to meet needs, and
- Contribution of the system to the overall defense operational and strategic plans.

For purposes of this guidebook, Program Management consists of the planning, organizing, staffing, controlling, and leading (POSCL) management functions. Other functions sometimes included in a program management context are scheduling, budgeting, monitoring, directing, and maintaining consensus and support. For this guidebook, these latter functions are considered subcategories of the basic five functions, when appropriate.

- *Planning* addresses the program mission, objectives, goals, and strategy and includes all management activities that result in selection of a course of action.
- *Organizing* considers the resources involved and how are they related. This function addresses the alignment of people, funds, equipment, facilities, etc., and the structure of the organization in order to meet program goals; it identifies:
 - Authority—The power to make final decisions
 - Responsibility—The obligation to perform assignments
 - Accountability—The state of being answerable for the completion of an assignment.
- *Staffing* addresses the qualifications and special skills that may be required

for persons assigned to each position in the program and the time phasing of assignments.

- **Controlling** is the function during which the manager monitors, measures, evaluates, and corrects program activities to ensure that actual operations conform to plans.
- **Leading** is the process whereby one individual exerts his/her influence over others in a group. Directing, an element of leadership, is the process of implementing, through the talents of others, the plans to meet program objectives. This includes training, supervising, delegating, motivating, counseling, and coordinating.

In a broad sense, the *planning phase* includes the tasks associated with defining the work requirements, specifying the quantity and quality of work, identifying resources, and organizing them to best carry out the program. Likewise, the *management or execution phase* includes the tasks of monitoring progress, comparing actual to predicted outcomes, analyzing the impact of differences between planned and actual achievements, and adjusting the program as necessary.

2.2 THE EVOLUTION OF PROGRAM MANAGEMENT

Formal program management came to the forefront in the late 1950s. The need to develop and implement a management approach to manage large-scale military systems, both weapons and support systems, stimulated the government and aerospace industry to devise the means to plan and execute complex programs. As the cost of weapons systems increased and the intensity of the Cold War grew, DoD also

felt the need to predict the cost, schedule, and performance of its new systems. Military organizations (predecessors of current “*acquisition*” organizations), in conjunction with defense contractors, developed much of the early theory and practices of program management as new technologies emerged.

The use of “task teams” or program teams and other organizational entities led to the emergence of a program management philosophy for integrating activity in organizations. As the program management discipline evolved, organizations developed special techniques for planning, organizing, staffing, controlling, and leading programs to integrate those activities from a focal point in the organizational structure. Moreover, program management addressed the elements of technical performance, cost, and schedule on a continual rather than one-time basis in the evolution of a program and considered them within the context of an organization’s operational (short-term) and strategic (long-term) objectives.

DoD has recently improved management with the introduction of the concept of Integrated Product and Process Development (IPPD) and Integrated Product Teams (IPTs). IPPD integrates all acquisition activities to optimize system development, production, and deployment. Key to the success of this concept are the IPTs, composed of qualified and empowered representatives from all appropriate functional disciplines who work together to identify and resolve issues. IPTs are the foundation for program management. One of the tenets of IPPD is the use of event-driven scheduling, which relates program events to their accomplishment and accomplishment criteria. Its use reduces risk by

ensuring that product and process maturity is incrementally demonstrated prior to beginning follow-on activities.

2.3 THE ACQUISITION PROCESS AND SCHEDULING

For the management of programs, the DoD acquisition process provides a framework that consists of a series of phases and milestones. The phases are a logical means of progressively translating broad mission need statements into well-defined system-specific requirements and ultimately into operationally effective, suitable, and survivable systems. Each phase is designed, among other things, to manage/reduce the risks, ensure affordability, and deliver the system to the user as soon as possible. Milestones are the points in time where decision makers evaluate the status of the program and determine if the program should proceed to the next phase. Prudent consideration of schedule implications is important in all phases of a program.

Milestone Decision Authority (MDA) and Service acquisition officials are encouraged to tailor programs to eliminate phases or activities that result in little payoff in terms of fielding time or cost. To effectively tailor a program, managers must understand scheduling, resource availability and allocation, and the risk associated with the tailoring.

An acquisition strategy defines the business and technical management approach to meet objectives within schedule and program constraints. A primary goal is to minimize the time and cost of satisfying a valid need, consistent with common sense and sound business practices. A PM prepares a preliminary acquisition strategy at Milestone 0 and updates the strategy to

support each milestone decision by describing activities and events planned for the upcoming phase and relating the accomplishments of that phase to the program's overall, long-term objectives. The acquisition strategy is first formally approved and published at MSI, Program Initiation. It provides a master schedule for research, development, test, production, fielding, and other activities essential to program success. This master schedule also serves as the basis for formulating functional plans and schedules.

As a program evolves through subsequent phases, new information becomes available that permits refinement of schedules and assignment of resources. Understanding of program risk becomes more specific as the system under development is defined, thereby allowing identification of risk-handling initiatives and their effect on schedule. Schedule considerations are an integral part of any Source Selection process, from preparation of the Request for Proposal (RFP) through proposal evaluation. After contract award, the schedule serves as a basis to determine progress and assess the need for management action.

Government developers should design their contracts with industry to allow time for milestone decisions, permit demonstration of exit criteria in time to support milestone reviews and to reflect expenditure of money with the program's funding profile. A good acquisition strategy allows fiscal control without delaying the acquisition decisions or contracts while adequately considering risk. In other words, it reflects thoughtful schedule and resource planning.

As a key element of the planning process, PMs must update the schedule as more is learned about the program and as changes occur.

With each new update, program cost, time, and requirements may change. PMs must respond by changing the mix and level of resources and continuously updating the program plan and the schedule as needed.

2.4 RISK MANAGEMENT AND SCHEDULING

DoD defines risk management as “the act or practice of controlling risk. It includes risk planning, assessing risk areas, developing risk-handling options, monitoring risks to determine how risks have changed, and documenting the overall risk management program.”² As part of their responsibility to manage risk, PMs must consider risk in their planning and scheduling practices. Risk management is concerned with the identification of uncertainties that threaten cost, schedule, and performance objectives, and the development and implementation of actions to best deal with those uncertainties.

Risk management and scheduling are closely tied. Consideration of one requires a reassessment of the other. For example, in creating the strategy and plans to handle program risk, a PM must consider how the approach affects the program schedule. Similarly, any tradeoffs between cost and performance must take into account schedule implications. Conversely, any change to the program schedule must consider the impact on the overall program objectives and on cost and performance. The challenge is to develop a plan that balances risk, cost, schedule, and performance.

Schedule risk is defined as the likelihood and consequences of failing to meet the program schedule, and it is an integral part of program risk. This topic is covered in Chapter 3.

ENDNOTES

¹ DoDD 5000.1, *Defense Acquisition*, March 15, 1996. (Being revised and updated as of 1 January 2000)

² *Ibid.*

3

PROGRAM MANAGEMENT AND SCHEDULING

As discussed in the previous chapters, scheduling is one of the most powerful tools available to the PM, and its effective application is essential to program success. While it is a key element in performing all program management functions, it is also critical to the accomplishment of planning and controlling management functions. This chapter discusses scheduling in the context of these two functions and addresses the essential elements and considerations in schedule planning.

3.1 PROGRAM PLANNING AND SCHEDULING

Program planning is the process of determining what needs to be accomplished, by whom, when, and under what resource constraints. It is arguably the most important of the program management functions. Without a sound and comprehensive plan, it is virtually impossible to develop a meaningful budget, effectively organize and staff the program office, direct the actions of the program office, or monitor and control the program. In addition to determining the “what, where, who, with what, and when” of a program, planning also helps to identify risk areas and ways to handle the risk, and establishes the program baselines.

There are a number of products of the planning process. Among them are:

- **Acquisition Strategy**—This is the comprehensive, integrated plan the program will follow. It provides an overall concept

of the program that functional plans will lay out in greater detail and reflects the strategy that will be followed to meet program objectives and to handle risk in the program. The acquisition strategy includes a program structure/schedule which depicts a visual overview and picture presentation of the acquisition strategy. This schedule is a single diagram similar to the diagram shown in Figure 3-3, and defines the relationship among acquisition phases, decision milestones, solicitations, contract awards, systems engineering design reviews, contract deliveries, test and evaluation activities, production releases, and operational deployment objectives. It includes quantities to be procured and delivered by fiscal year by phase in terms of prototypes, engineering development models, low-rate initial production and full-rate production. The program structure/schedule is a key decision review/milestone document; it summarizes the program and is built from many other more detailed schedules found in functional plans such as test and evaluation, contracting, etc. It is sometimes referred to as the Master Program Schedule (MPS). In addition to this top level structure/schedule, the PM may deem it necessary to have more detailed program management Integrated Master Plans (IMP) and Integrated Master Schedules (IMS) prepared and submitted by the contractor during the proposal process. See the *DSMC Acquisition Strategy Guide*¹ for information on structuring, developing, and executing an acquisition strategy.

- **Functional Plans**—These are the detailed plans that lay out the approach to be taken in the different functional areas. Examples include: the Test and Evaluation Master Plan (TEMP) and Command, Control, Communications, Computers, and Intelligence (C4I) Support Plan, which are required; and the Systems Engineering Master Plan (SEMP), Logistics Support Plan (LSP), etc., which are optional.

- **Work Breakdown Structure (WBS)**—The WBS provides a basic framework for identifying each element of a project in increasing levels of detail. In essence, it describes the way work is performed. The WBS also provides a coherent method for reporting progress toward plan goals.

- **Integrated Master Plan (IMP)**—The IMP is an event-based plan depicting the overall structure of the program and the key processes, activities, and milestones. It defines accomplishments and criteria for each event.

- **Integrated Master Schedule (IMS)**—The IMS shows the detailed tasks and timing for events in the IMP and depicts the logical progression of events throughout the program. These tasks should be directly traceable to the IMP and the WBS.

- **Schedules**—A series of schedules are developed during the planning process, all of which are derived from the IMS. These schedules are developed to show the details required to complete key activities and milestones.

- **Budget**—The budget reflects the cost of the integration of the scope, schedule, and resource plan for accomplishing the work.

Scheduling is a critical element in the planning process. In addition to being an output of the process as discussed above, it also contributes to the development of the other outputs. The early involvement of people who are knowledgeable and experienced in scheduling techniques can contribute to the effective translation of strategic concepts and ideas into detailed logic diagrams, depicting the program activities and relationships among activities. This can be very useful in developing budget and detailed functional plans, especially in identifying the required resources and leveling them throughout the activities.

The WBS and the IMP/IMS are important concepts used in the scheduling process and are described in more detail in the following sections.

3.2 WORK BREAKDOWN STRUCTURE

During the 1960s, the impetus to develop a tool to help project managers define a project in a cohesive way gave rise to the development of the WBS. WBS use has not been confined to the DoD and its contractors; rather, it is now used in many commercial enterprises. Several years after the emergence of the WBS concept, DoD published a WBS standard for DoD acquisition organizations as well as their contractors to use: MIL-STD-881B. This standard has been superseded by a handbook, MIL-HDBK-881, dated 2 January 1998. It contains much of the same information as its predecessor but is not directive in nature and is for guidance only.

MIL-HDBK-881 defines a WBS as:

- A product-oriented family tree composed of hardware, software, services, data, and facilities. The family tree results from

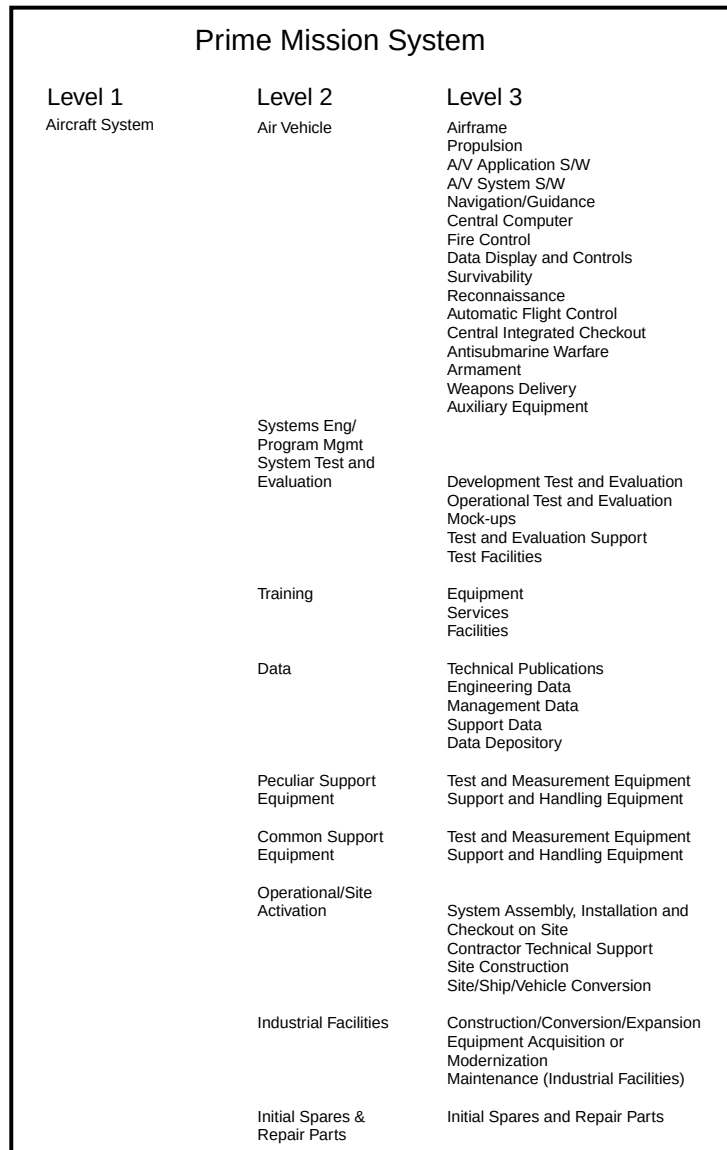


Figure 3-1. Generic Aircraft System Program WBS

systems engineering efforts during the acquisition of a defense materiel item.

- A WBS displays and defines the product, or products, to be developed and/or produced. It relates the elements of work to be accomplished to each other and to the end product.
- A WBS can be expressed down to any level of interest. However, the top three levels are as far as any program or contract needs to go unless the items identified are

high cost or high risk. In that case, the WBS should be taken to a lower level of definition.

WBS's apply to seven specific categories of defense materiel systems: aircraft; electronic/automated software; missile, ordnance; ship; space; and surface vehicle. The WBS should be developed and maintained based on the systems engineering efforts throughout the system's life cycle.

Figure 3-1 is an example of a level 3 program

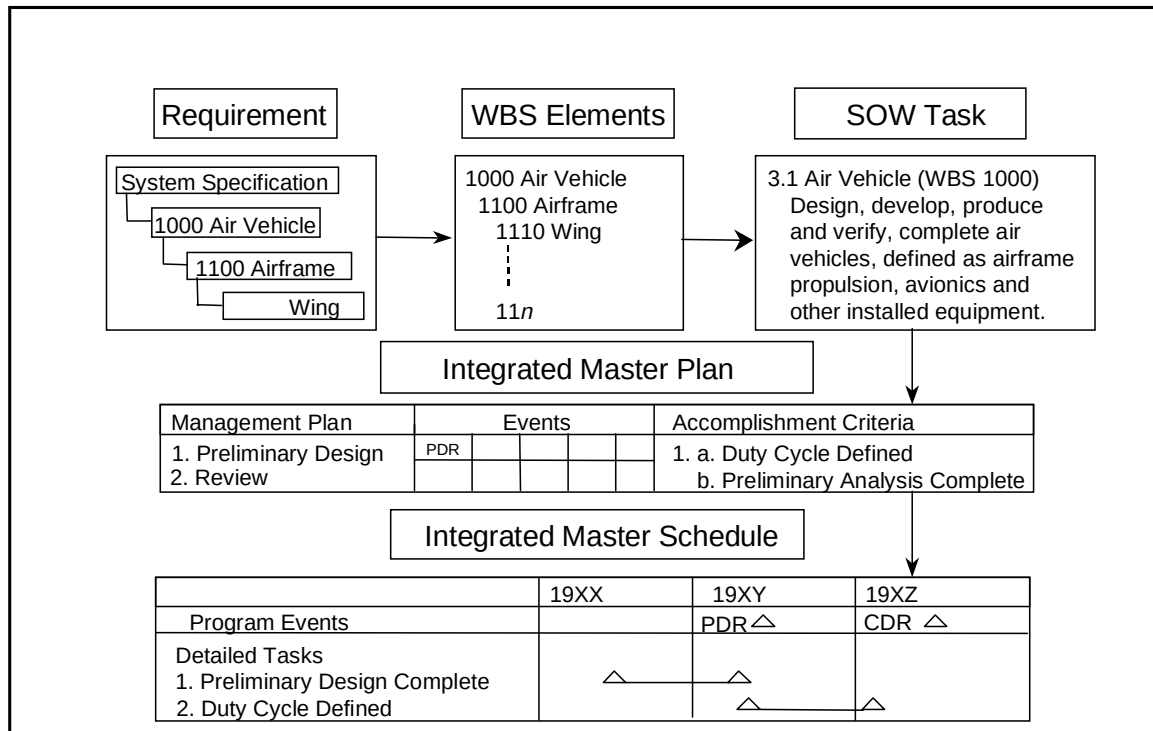


Figure 3-2. IMP/IMS Sample

WBS for an aircraft system. The WBS approach provides a powerful technique for scoping a project in a manner that provides management with insight into project requirements and performance—from the very top, or systems level, to the lowest level of definition of a work product. Planning work using the WBS approach serves as the basis for both estimating and scheduling resource requirement.

3.2.1 Integrated Master Plans/Schedules

The IMP is a very effective tool of program management. It is the contractor's event-based plan for accomplishing the Statement of Objectives (SOO) and Statement of Work (SOW). It identifies the key activities, events, milestones, and reviews that make up the program. A program IMP is prepared initially by the contractor and

provides the basis for development of subordinate IMPs and other functional plans. It also identifies those events and activities that will be included in the IMS.

The IMS is a networked multi-layered schedule generated by the contractor that begins with all identified IMP events, accomplishments, and criteria. It shows the expected start and finish dates of these events. It contains all contractually required events/ milestones such as reviews, tests, completion dates, and deliveries specified in the program WBS.

The IMP is prepared by the contractor during the proposal process. It is maintained by the government program office and contractor through a collaborative effort involving all the program “stakeholders.” In some cases, a preliminary IMP may be developed by the government,

with industry input, during pre-solicitation. The IMP defines contract requirements stated in the RFP and contractors use it to develop the IMS and detailed functional schedules. These integrated schedules tie together all program tasks by showing their logical relationships and any constraints controlling the start or finish of each task. This process results in a hierarchy of related functional and layered schedules derived from the WBS that can be used for monitoring and controlling program progress. An example (suggested format) of an IMP/IMS for an aircraft development program is depicted in Figure 3-2. The IMS should be expanded down to the level of detail appropriate for the scope and risk of the program. Programs with high risk should show more detail in the IMS to provide the visibility necessary to manage risk. A more detailed discussion of IMS's is contained in Appendix A. A Data Item Description (DID) has been developed by the Department of Defense for the IMS; the identification number is DI-MISC-81183A. This DID is at Tab 1 to Appendix A.

3.3 PROGRAM CONTROLLING AND SCHEDULING

The controlling function contains all those activities that a program manager undertakes in attempting to ensure that the actual program conforms to the developed plan, to include the implementation of necessary action to get the program back on the plan if possible. To control a program, the PM needs the means to monitor program progress against the established plan, or the program baseline. In its simplest form, the program schedule can serve as a baseline against which to measure progress. If there are indications that an activity is falling behind schedule, this information can be used by the manager as a basis for

corrective action. However, considering schedule information alone can be misleading. Successful management requires the integration of the technical, schedule, and cost aspects of a program. Thus, some form of integrated performance measurement is needed for monitoring and controlling a program. The concept of earned value management provides such a capability.

3.3.1 Earned Value Management

Earned Value Management (EVM) is the use of an integrated management system that coordinates work scope, schedule, and cost goals and objectively measures progress toward these goals.² The purpose of EVM is to provide contractor and government PMs with accurate data to monitor program execution. It is also intended to provide an adequate basis for sound contractor and government decision making by requiring that the contractor's internal management control systems produce data that: (1) indicate work progress; (2) properly relate cost, schedule, and technical accomplishments; (3) are valid, timely, and able to be audited; and (4) provide DoD component managers with information at a practical level of summarization.

The DoD earned value process holds the contractor responsible for effective implementation of an EVM system. DoD does not prescribe a specific EVM system for contractors to use; instead, it has established a set of criteria that the contractors' systems must meet to be acceptable. The requirement to use an EVM system that meets the criteria is dependent on the type and size of the contract. DoD Regulation 5000.2-R defines the contracts that must use such an EVM system as well as the criteria for an acceptable system. For contracts that do

not meet these thresholds, contractor management information is provided to the government using a Cost/Schedule Status Report (C/SSR). This report should be based on an underlying management system that uses an earned value approach for tracking progress. Such a system does not have to meet the EVM criteria of DoD 5000.2-R; however, the government should negotiate with the contractor to ensure that the system does emphasize earned value methodology.

Basically, earned value relates resource planning to schedules and to technical performance requirements. All work (identified in the Program and Contract Work Breakdown Structures) is planned, budgeted, and scheduled in time-phased “planned value” increments constituting a performance measurement baseline. As work is performed, it is “earned” on the same basis as it was planned, e.g., in budgeted dollars or labor-hours. *Planned value* [budgeted cost of work scheduled (BCWS)] compared with *earned value* [budgeted cost of work performed (BCWP)] measures the dollar volume of work planned versus the equivalent dollar value of work accomplished. The difference, if any, is termed the “schedule” or “accomplishment” variance. Earned value (BCWP) compared with the actual cost of the work performed (ACWP) provides an objective measurement of cost performance. Any difference is called the cost variance.

The three data points—BCWS, BCWP, and ACWP—are outputs of the EVM system and are provided to the government on a monthly basis. They, along with the schedule and cost variances, provide the basic information needed to determine program status at a given time, and to identify the elements that are driving each of the variances.

Analysis of these data points over time also identifies trends that may affect or impact the future performance for the remainder of the contract. This is important; it enables PMs to isolate causes of recurring variations and to take alternative actions that will improve performance. Quantitative techniques can also be applied to EVM data to predict program performance at completion in terms of cost and schedule. The DSMC *EVM Textbook*³ provides detailed information on the application of EVM techniques.

Success of EVM techniques is dependent on several things, not the least of which is effective and accurate contractor scheduling. EVM system criteria do not require contractors to use specific scheduling techniques. However, they do seek formality, consistency, and discipline throughout the scheduling process. The contractor's scheduling system:

- Provides a summary or master schedule and related subordinate schedules showing vertical traceability from the master to the detailed schedules
- Identifies key milestones and activities and indicates significant constraints and relationships
- Provides current status and forecast of completion dates of scheduled work that enable comparison of planned and actual status of program accomplishments
- Establishes a schedule baseline
- Provides horizontal traceability showing interrelationships among various activities.

The scheduling baseline usually consists of a hierarchy of vertically integrated schedules, with each lower-level schedule more fully identifying and expanding the tasks necessary to meet the program's objectives. Generally, three sets of schedules are prepared:

- **Master Schedule (MS)**—The top-level schedule that summarizes key program activities and milestones and depicts the logical progression of events throughout a contract. Program Structures/Master Program Schedules developed by the government PM reflect information contained in the contractor's Master Schedule.
- **Intermediate Schedules**—The schedule that ties the MS to the detailed schedules. It allows for rollup of detailed schedules to summary levels that are useful for management.
- **Detailed Schedules**—The schedules at the control account or work package level. Work packages must be distinguishable from each other and must include definite start and completion dates. They are prepared by the contractor with government concurrence.

3.4 SCHEDULE PREPARATION

As stated earlier, scheduling is a critical element of the planning process. Conversely, planning is critical to the development of effective schedules. Near-term scheduling can and should be accomplished in sufficient detail to support management at each level. Far-term, or rolling-wave, scheduling will be less precise, accounting for the alternative paths that the program may take. As the program approaches each phase, the schedule for that phase will be fleshed out with

more detailed schedule information. The schedule for the out-year phases will be adjusted based on the most current information. However, this should not be taken as a license to make easy changes in the schedule. Every effort should be made to maintain the original schedule.

In all programs, there will always be a requirement to make tradeoffs between cost, schedule, and performance. Cost includes all resources—people, money, equipment and facilities. Performance includes quality and supportability parameters. The best schedule supports the best tradeoff between these competing demands, taking into account the risks that are associated with each tradeoff and the impact on the overall program.

The preparation of program schedules should be done within a formal structure. The procedures to be followed should be specified, to include such things as software applications to be used, the formats for displays, and the type of symbols to be used. Also, clear lines of authority and responsibility should be established. The remainder of this section discusses the logical steps that should be followed in preparing schedules, to include sources of information, tools and techniques, and the outputs of the steps. These steps are based on those described in the Program Management Institute's *Guide to the Program Management Body of Knowledge*.⁴ While they present a somewhat different approach than the IMP/IMS method, they have generic applicability over the range of planning methods.

3.4.1 Activity Definition

This step involves the identification and definition of those activities that must be

accomplished to achieve the objectives. The WBS is a logical source for such descriptions. If a WBS is not available, more planning must be done in order to identify project activities clearly. Other inputs to the definition step are the program scope, historical information, program constraints and assumptions, and events required by the Planning, Programming, and Budgeting System (PPBS), the requirements generation system, and DoD acquisition management process.

Decomposition and templates are techniques commonly used in activity definition. Decomposition involves the successive breakdown of program elements into smaller, more manageable components, which eventually describe the activities to be scheduled. This technique is essentially the same used in WBS development. A template is an activity list or WBS element from another similar program that can serve as a model for the current program and provide a starting point for defining specific activities.

The primary output of this step is the activity list, which should contain a complete description of each of the activities necessary to complete the program. This list should be linked to the WBS, which should be reviewed and revised/clarified as necessary to incorporate changes resulting from the activity definition process. Supporting details for each activity, such as constraints and assumptions, should also be developed and documented.

3.4.2 Activity Sequencing

This step involves the accurate identification of constraints/relationships among activities and establishing the order in which the activities will be accomplished.

There are several inputs to this step:

- The activity list developed in the activity definition step,
- The product description and characteristics,
- Mandatory constraints/dependencies, such as the fact that a prototype must be fabricated before it can be tested,
- Discretionary constraints/dependencies developed by the program management team based on “best practices” or specific sequences desired by management,
- External dependencies, such as availability of test sites, and
- Other constraints and assumptions.

A number of tools and techniques are useful in developing the logic diagrams that reflect the desired activity sequencing. They include various network scheduling techniques that are discussed in Chapters 4 and 6. In addition, a number of scheduling software programs develop activity sequencing. Their selection and use are discussed in Chapter 9.

The output of this step is a network diagram that reflects the sequence of activities based on the inputs described above. This diagram should be augmented with a narrative description of the sequencing approach and a detailed discussion of any unusual or complex sequences. Activity lists should be reviewed and revised to reflect any changes necessitated by activity sequencing.

3.4.3 Activity Duration Estimating

Activity duration estimating is the determi-

nation of the time required to complete the activities that make up the program. This is one of the most difficult aspects of schedule development and should be performed by people who are most familiar with the activity. Two key inputs to the estimation process are the resources required and assigned for the activity and the capabilities of the resources assigned. Historical information from other programs and from commercial databases can also be helpful in developing accurate estimates.

The following techniques are commonly used in estimating activity durations:

- Expert judgment guided by historical information,
- Analogous estimating based on experience of similar programs,
- Parametric estimating based on formulas describing relationships among program parameters and time, and
- Use of simulation to develop distributions of probable duration of each activity.

The output of this step is an estimate of the likely amount of time to complete each activity. These estimates should also include a range of possible values, e.g., 3 weeks $\pm$ 1 week, and a clear statement of the assumptions made in the estimation process.

3.4.4 Schedule Development

This step involves the development of realistic start and finish dates for each activity. An iterative process, schedule development takes into account activity sequencing, duration estimates, resource

requirements and availability, calendars that show when work can be performed, constraints, assumptions, and risk.

The output of this step is a set of schedules for the program. These include the master program schedule and the supporting detailed schedules, which should reflect the best balance possible between competing demands of time and resources. They should also take into account the risk associated with time, cost, and performance tradeoffs and the impact on the overall program.

A number of techniques and tools are useful in developing schedules, many of which are contained in various scheduling software applications. Many of these applications contain the capability to perform various types of mathematical analyses to calculate theoretical start and finish dates for each activity based on the overall sequencing of the program activities. Two of the more commonly known analysis techniques are critical path method (CPM) and the Program Evaluation and Review Technique (PERT). They are discussed in greater detail in Chapter 6.

Other scheduling development techniques that are commonly used focus on schedule development in light of resource (time, people, funds, material) constraints. These techniques provide the means to manage the affect of these constraints through the compression of activity duration and the leveling of resources throughout activities. Schedule compression and resource leveling are discussed in more detail in Chapter 6.

3.4.5 Schedule Control

The final step in the schedule preparation

process is to identify schedule variations and to manage actual changes to the developed schedules. A schedule change control system that defines the procedures by which changes can be made should be established and integrated into the program's overall change control system. The schedule change control system should address such things as the methods of schedule performance tracking and the approval process for authorizing changes. The need for schedule changes can be caused by a number of factors, to include:

- Failure to achieve planned dates for specific activities or events,
- Internal program management assessment and replanning, and
- External direction, such as reallocation of funding.

When evaluating these factors, it is important to determine what, if any, schedule change is necessary. For example, if an activity that is not on the critical path is not completed as planned, it may not have any effect on the overall program schedule. Consequently, it may not require any significant schedule change.

The schedule change control system should also include procedures for implementing schedule changes. Such procedures should address the requirement to keep all program stakeholders, especially the users, advised of any significant schedule changes. They should also address the process for adjusting the schedule baseline and the overall program plan when necessary schedule changes are severe. The change control system can also serve as a good database of lessons learned. Consequently, information concerning sched-

ule variations, their evaluation, and the development of corrective actions should be documented and made readily available to members of the program's management team, and to other programs.

3.5 SCHEDULE RISK

In Chapter 2, we discussed the relationship between risk management and program scheduling. In this section, we discuss the risk associated with the program schedule. Uncertainty exists in every schedule. It is impossible to predict, with complete confidence, the length of time necessary to complete an activity, meet a milestone, or deliver a system. Little information exists in the early phases of a program, and planners must rely on personal experience and the estimates of experts. As a program progresses through the acquisition cycle, more information becomes available. Schedules developed in the latter phases of a program are based on more information and analyses, but they still lack complete certainty. Uncertainty introduces the element of risk in the planning process. Schedule risk is the likelihood of failing to meet schedule plans and the effect of that failure.

When creating a schedule, or when determining overall program risk, the PM must assess the risk associated with the schedule. One technique for assessing this schedule risk involves estimate contributions for each activity's duration and aggregating these distributions using a Monte Carlo simulation or other analytical tools. The resulting program-level schedule is then analyzed to determine the actual schedule risk and to identify the schedule risk drivers.

This technique uses a range of times that it will take to complete each activity instead

of single-point estimates. This approach results in a more realistic estimate of schedule risk because it accounts for much of the uncertainty inherent in the use of single-point estimates. Their use invariably leads to underestimating the time required to complete the program and, therefore, schedule overruns, primarily because the point estimates do not adequately address the uncertainty inherent in the individual activities.

This range of values for each activity defines a probability distribution for the duration of the activity. These distributions are then combined to determine the program-level schedule estimate. This approach enables PMs to estimate early in a program if there is a significant likelihood of overrunning the program schedule and by how much. It also identifies program activities that are on the “highest risk path.”

This technique can be used in any acquisition phase beginning with the completion of the first statement of work. The schedule probability distribution function for each key activity should be developed as soon as the activity is included in the master schedule. The distribution functions should be periodically reviewed and revised, if necessary, at least once per phase.

The technique should be applied by a small government-industry team consisting of schedule analysts and technical experts who understand the significance of previous risk performance assessments. See the *DSMC Risk Management Guidebook*⁵ or the *Defense Acquisition Deskbook*, Section 2.5.2.4⁶ for more details on the application of this technique.

3.6 SUMMARY

Scheduling is critical to the successful execution of the planning and controlling functions of program management. In the planning phase, it contributes to the development of detailed functional plans

and budgets and to identification and allocation of required resources throughout program activities. During this phase is developed a set of integrated multi-layered schedules that tie together all program activities, showing their logical relationships and any constraints. The level of detail developed for these schedules depends on program scope and risk. This process provides a hierarchy of functional and layered schedules that can be useful in monitoring and controlling program progress.

Effective program control depends on some form of integrated cost, schedule, and technical performance management, such as the earned value management system (EVMS). Effective scheduling is key to the success of this technique. EVMS criteria do not dictate the use of specific scheduling techniques. However, they do seek formality, consistency, and discipline throughout the scheduling process.

A five-step process for schedule preparation that is commonly used in program/project management includes:

- Activity definition,
- Activity sequencing,
- Activity duration estimation,
- Schedule development, and
- Schedule control.

Risk is inherent in all programs, and scheduling is one element of risk. Uncertainty introduced in estimating the duration of each activity causes most schedule risk. PMs must assess the likelihood of failing to meet schedule plans and the impact of that failure. Probabilistic techniques have proven to be very useful in conducting these assessments.

PROGRAM STRUCTURE/SCHEDULE (EXAMPLE)

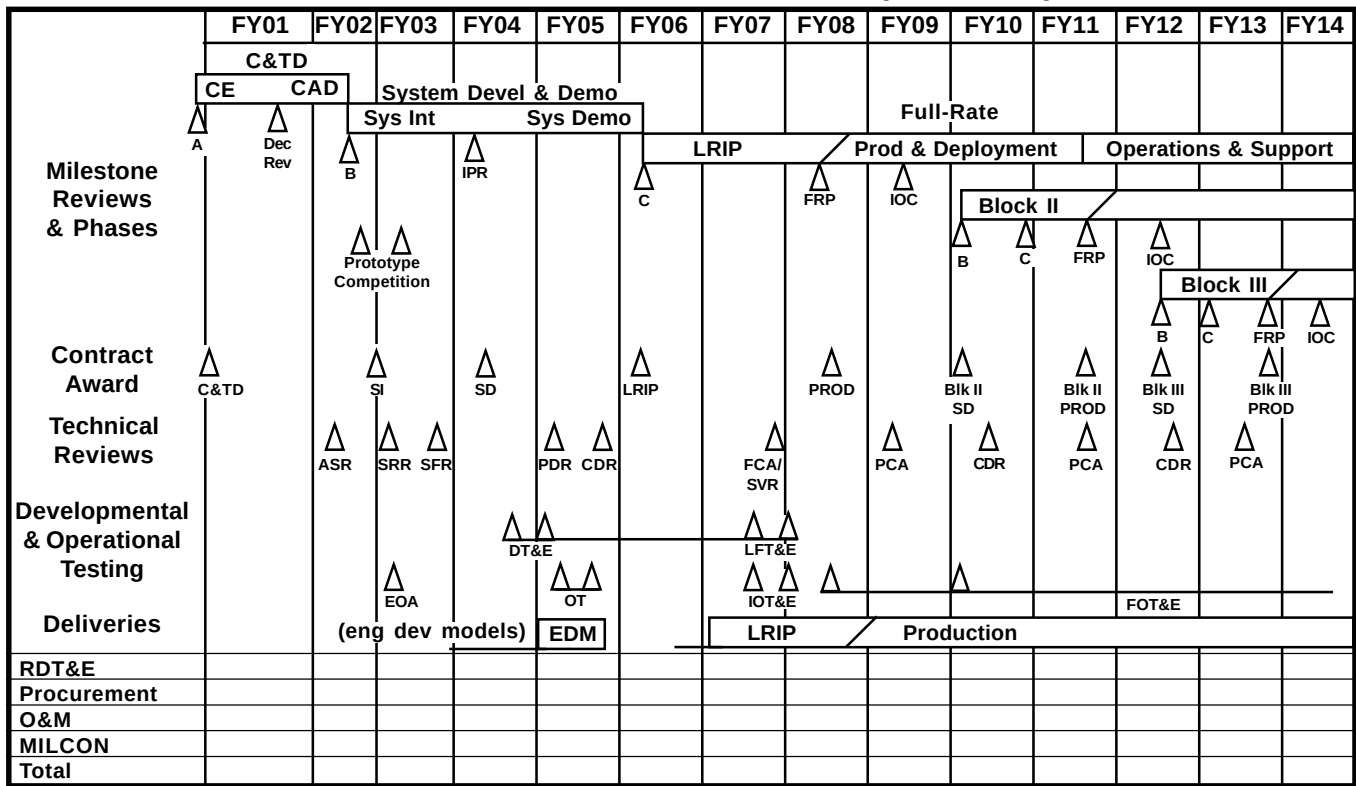


Figure 3-3. Program Schedule/Structure (Example)

ENDNOTES

- ¹ Defense Systems Management College, *Acquisition Strategy Guide*, Fort Belvoir, VA, January 1998.
- ² Defense Systems Management College, *Earned Value Management Textbook*, Fort Belvoir, VA, April 16, 1998,
- ³ *Ibid.*
- ⁴ Program Management Institute, *A Guide to the Program Management Body of Knowledge*, Newtown Square, PA, 1996.
- ⁵ Defense Systems Management College, *Risk Management Guidebook*, Fort Belvoir, VA, May 1999.
- ⁶ Information on schedule risk techniques is in the Risk Assessment Techniques of the Front Line Wisdom & Advice portion of Section 2.5.2.4, Defense Acquisition Deskbook.

4

SCHEDULE TYPES AND THEIR EVOLUTION

4.1 INTRODUCTION

Previous chapters of this guide stress the point that scheduling is an intrinsic, indispensable part of program management and a key output of the planning function of that process. They also describe the relationship between the program Work Breakdown Structure and scheduling, and introduce the concepts of the Integrated Master Plan and the Integrated Master Schedule. Properly prepared and accurate schedules are invaluable tools in the overall management of programs. They provide a road map of where the project is going, the resources required to accomplish the various project tasks, a means to determine progress, and an effective way to present status information. This chapter contains information on the various types of schedules generally in use today, their characteristics, advantages and disadvantages, and how they have evolved. Subsequent chapters provide more detailed information on each of the schedule types, along with information on the selection and use of scheduling software.

4.2 SCHEDULE TYPES

Schedules can be presented in a variety of ways. Regardless of how they are displayed, schedules essentially convey information concerning one (or a combination) of the following categories:

- Activities or tasks to be accomplished over a period of time, and

- Events or milestones, that take place at a point in time, such as a Defense Acquisition Board (DAB) milestone review.

Dependencies or constraints among activities or events.¹

Currently, four types of schedules are in common use and depict the categories of information described above. They are the Gantt or bar chart, the milestone schedule/chart, the network schedule, and the production schedule. The evolution, characteristics, and uses of each of these schedules are described in the following paragraphs, and a more detailed treatment of each of them is contained in subsequent chapters.

4.2.1 Gantt and Milestone Charts

Gantt charts and milestone charts are normally combined to show a program's schedule; therefore, they are discussed in this context. The Gantt chart is used to provide information concerning activities. It is commonly referred to as a bar chart, since it depicts an activity as a horizontal bar imposed over a time-line, or calendar. It shows the planned start and finish dates for the activity and may provide information about task progress, including schedule slips or gains. Figure 4-1 is an example of a simple Gantt chart that shows the planned schedule for four activities. Progress in accomplishing each activity can be shown on each of the bars, as shown by the shaded portions of activities 1 and 2.

The Gantt chart was the first formal scheduling technique developed. It dates back to the early 20th century when Henry L. Gantt first introduced it while working at the Frankford Arsenal during World War I. It was developed to provide a more formal and systematic way to schedule tasks when time was an important factor.

The Gantt chart has survived in its basic form to this day and continues to be widely used as a scheduling tool at all levels within organizations. Its value lies in its simplicity and its ability to convey considerable information in a clear and concise manner. In the past, the principal shortcoming of the traditional Gantt chart was its inability to clearly depict dependencies or constraints among activities, making it difficult to analyze schedules and optimize the allocation of resources to the activities. Some scheduling software programs now make it possible to show relationships, thereby

improving its utility. The Gantt chart is very useful in reporting project status and in managing individual activities or simple projects with few tasks.

Subsequent to the development of the Gantt chart, planners and managers used a similar approach to depict information about significant project events, focusing on specific points in time. These events represented project milestones—hence the introduction of the milestone chart. The milestone chart shows when an event is scheduled and when it is actually accomplished. Figure 4-2 is an example of a milestone chart showing the status of four events; each of these events represents the completion of the four activities shown in the example Gantt chart in Figure 4-1.

Like the Gantt chart, the strength of this milestone chart as a scheduling technique lies in its relative simplicity and its ability to concisely display project information,

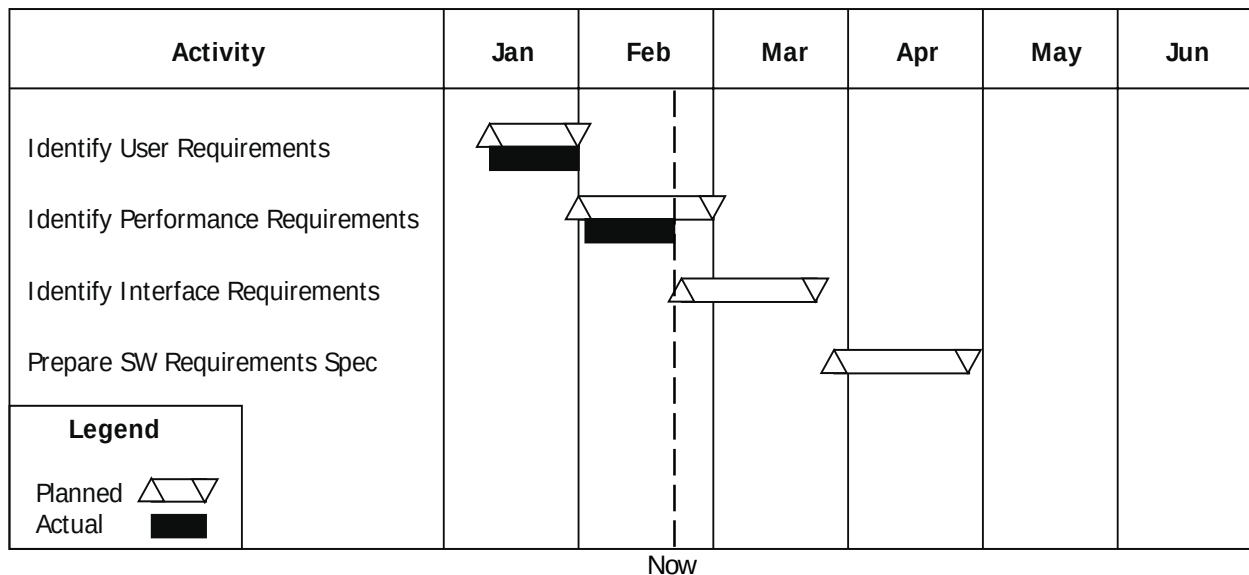


Figure 4-1. Gantt Chart Example

Event	Jan	Feb	Mar	Apr	May	Jun
User Requirements Identified	▲					
Performance Requirements Identified		△				
Interface Specs Identified			△			
SW Requirements Spec Completed					△	
Legend Planned △ Actual ▲						

Figure 4-2. Milestone Chart Example

especially at the “big picture” level. However, it does have shortcomings that limit its effectiveness in day-to-day project management. As shown in Figure 4-2, the milestone chart can depict the events corresponding to the completion of an activity.

However, it does not reflect the progress in accomplishing the activity. In this case, a manager relying on this milestone chart information could be surprised if the planned completion date is not achieved. With no warning or indicators of schedule slippage, the manager loses any flexibility in attacking the underlying problems causing the slippage. This shortcoming can be compensated for by the addition of intermediate events or through the use of combined Gantt and milestone charts. This is discussed in more detail in the next chapter.

Another weakness of the milestone chart is the difficulty to clearly visualize the relationships, dependencies, and constraints among the various project/program activities and events. In spite of these shortcomings, the milestone chart can be an effective way of presenting the project or program status at higher levels of management review.

Perhaps the biggest shortfall of the Gantt and milestone charts is that neither of them, nor the combination of both, allow detailed schedule analysis. However, every PM must know and understand Gantt and milestone charts for two simple reasons: everybody uses them, and normally, one of the first steps in the planning process is to construct a schedule using a Gantt chart.

4.2.2 Network Schedules

Network scheduling was developed to overcome the primary shortcoming of the Gantt and milestone charts—the inability to clearly portray the relationships, dependencies, and constraints among the project activities and events. A network schedule is a graphical display of a project, including a representation of these relationships. Figure 4-3 shows an example of a network schedule for a simple project.

In this example, the lines represent project activities A through H; the nodes represent the events associated with the beginning and end of the activities. The network shows the following constraints

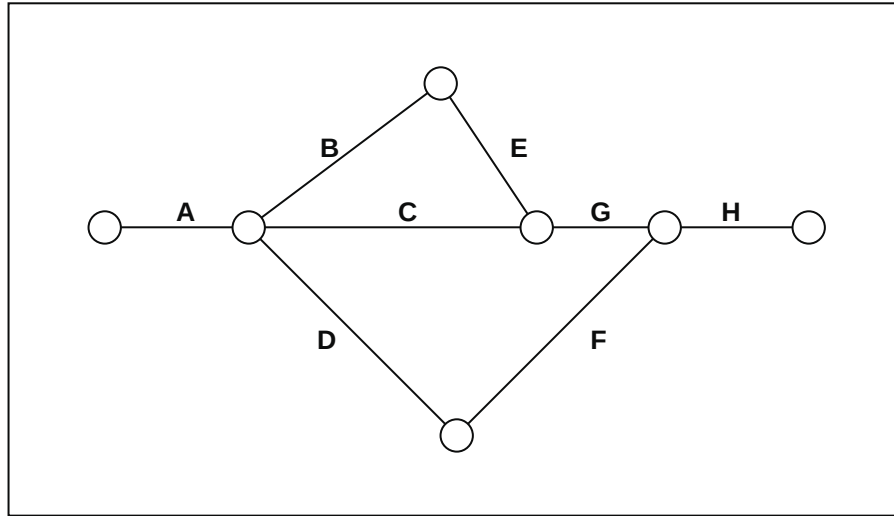


Figure 4-3. Network Schedule Example

among the activities: activity A must be completed before activities B, C, or D can begin; B must be completed before E can begin; F cannot begin until D is completed; G cannot begin until C and E are done, and H cannot begin until F and G are completed. In addition to showing this type of sequencing constraints, network schedules can also show the time and resources planned for each activity and thus provide managers with a mechanism to monitor and control the project. A later chapter covers network schedules in detail.

The advent of network schedules can be traced back to the 1920s and the evolution of operations research. Analysts realized the inability to depict dependencies and constraints was a major shortcoming of existing scheduling techniques, and attempted to solve the problem through the application of network theory. The translation of this theory into a usable scheduling tool was hindered by the inability to process network-related data in a timely fashion. The development of the computer provided the means to automate this data processing and, by the 1950s, the concept of network scheduling

was being applied to large, complex programs. The first major network scheduling technique developed was the Program Evaluation and Review Technique, or PERT, which was used as a management tool for scheduling and controlling the Navy's Polaris missile program. PERT enables managers to visualize the entire program, see interrelationships and dependencies, and recognize when and where delays are acceptable. One of the key features of PERT is the use of probability techniques to develop a set of time estimates for each program activity, making it particularly well-suited for programs where it is difficult to make accurate estimates with high confidence. Concurrent with the development of PERT, the construction industry developed a network scheduling system based on the concept of critical path. A project's critical path is the most time-consuming route through the network activities that must be completed in order to finish the project. This approach, named Critical Path Method (CPM), was designed to focus on performance time and total program cost. Some publications refer to CPM as the Arrow Diagram Method (ADM).

PERT and CPM scheduling techniques have many similarities. For example, each shows the relationships among activities and events, both include the project's critical path, and the structure of each allows analysis of the tasks to be done, resources assigned to do them, and the time associated with each task. Both techniques use nodes to represent events (beginning and end of activities) and lines to represent the activities.

A third network scheduling technique is the Precedence Diagram Method (PDM), which was developed subsequent to the PERT/CPM techniques. Its function is to permit a more accurate depiction of relationships among various activities than is possible using the other two techniques. PERT/CPM techniques are essentially limited to "finish-start" relationships (i.e., activity B cannot start until activity A is completed). The PDM technique can depict other relationships that permit a more accurate and realistic portrayal of the program's activities, such as "start-start" (i.e., activity B cannot start until activity A starts). The technique accomplishes this through the use of nodes to depict activities and lines to depict relationships. These three techniques are discussed in greater detail in Chapter 6. Network scheduling techniques provide managers with a powerful tool for scheduling and controlling their programs/projects. In general, they permit the graphic portrayal of project activities and relationships among the activities. This provides the basis for determining the project's critical path, predicting shortages, and identifying possible reallocation of resources to solve problems. Through the use of readily available software, network schedules are fairly easy to update and rework, thus providing managers with current program/project status information and control over activities and schedules.

In spite of the strengths of network scheduling techniques, there are some limitations. The value of network schedules is directly dependent on the validity of the time estimates for each activity. In addition, it is sometimes difficult to accurately portray all activities and relationships, especially for very large, complex programs. Thus, considerable "up front" work is required to develop an effective network schedule. Detailed networks, once developed, tend to be the focus of management attention when, in fact, there will undoubtedly be other factors not on the display that will require management attention.

4.2.3 Production Schedules

Production scheduling involves the planning, execution, and control of repetitive activities, such as the manufacture of a large number of identical items. Efficient production requires the proper balance of materials, facilities, and personnel skills. It also requires a means to monitor the production process.

The Line of Balance (LOB) technique, while not truly a scheduling tool, is such a monitoring technique that can provide early warning of potential problems that can affect program schedule. It is especially useful for monitoring repetitive processes where it is essential to balance inventory acquisition with the production process and delivery requirements. The LOB technique consists of four elements: (1) objectives of the program, i.e., contract schedule and actual deliveries; (2) production plan; (3) current program status or inventory; and (4) a comparison between where the program is and where it's supposed to be, (that is, program inventories versus the LOB). These elements are discussed in more detail in Chapter 7.

The origin of LOB is not clear, but it is believed it was developed to help manage defense-related contracts in the 1940s and 50s. It is still used today in both defense and commercial industry. While government PMs or their staffs will probably not need to directly develop or apply the LOB technique, they should understand it and realize that it can be a valuable tool for contractors to monitor the status of production contracts and to present status information.

This technique can point out problems before their impact on finished product deliveries shows up, thereby allowing managers to make corrections. It also allows managers to see, in the middle of a contract, whether they can meet the contract schedule if they continue working as they have been. Another advantage of LOB is that it focuses attention on the production activities where there are problems, thereby facilitating initiation of corrective action.

There are some limitations with the LOB technique. First, it is best suited for production and/or assembly-type processes that are stable. The activities that make up the production plan must be definable and well understood. Second, while this technique pinpoints where a problem exists, it cannot identify the specific problem.

4.3 SUMMARY

Each scheduling method has strengths and limitations. Program Managers must be familiar with all of the techniques and choose

the method that allows them to meet their goals. The choice of schedule type depends on a number of factors, such as, the purpose of the schedule, its intended use, and the decisions to be made from the information presented. For example, day-to-day management of a project consisting of a number of related and complex activities may require a schedule that depicts the tasks, their planned duration, dependencies, progress, and resources allocated to each of them. If a PM must do detailed schedule analysis of this type of project, then the PM will most likely use a network schedule. This method is the only way to use probability distributions for time estimates rather than completing an activity and project in a certain time.

On the other hand, the management of a single activity may require a schedule that reflects only the time planned for accomplishing the task and the current status. Schedules showing only events, such as the completion dates of planned activities, or bar charts may be sufficient in those cases when the audience may not be concerned with the details of the activities.

As a rule of thumb, Gantt and milestone charts are useful to present information and summarize program activities. They are also usually the starting points for detailed planning and creating a network schedule. Network schedules are usually created for detailed planning and analyses. They are necessary to determine the feasibility of meeting program goals, assessing risk, and conducting sensitivity analyses.

ENDNOTES

¹ Quentin W. Fleming, John W. Bronn, and Gary C. Humphries, *Project and Production Scheduling*, Chicago, IL, Probus Publishing Co., 1987, p. 45.

5

GANTT AND MILESTONE CHARTS

5.1 DESCRIPTION

As discussed in Chapter 4, the Gantt chart is one of the oldest planning tools in existence and is still used today at all levels of project management. For example, PMs use Gantt charts to report information concerning program activities at milestone decision briefs, while engineers may use them to manage the tasks associated with design activities. Because PMs often use Gantt and milestone charts to report information to review groups, they are treated jointly in this chapter.

In its simplest form, a Gantt chart is a schedule that shows the start/stop dates of a program's individual activities. It uses symbols superimposed on a calendar to provide information about the original plan, the status of the activity, and any forecasted changes to the plan.

There is no standard set of Gantt chart symbols. Planners should define them and consistently use them throughout the chart. Figure 5-1 shows an example of the symbols that could be used in Gantt charts.

The schedule is displayed as a series of horizontal bars representing the duration of activities. A manager may show actual progress against the schedule by shading in each bar as activity progresses or may use a colored bar that is parallel to the schedule bar. Figure 5-2 shows a simple Gantt chart that illustrates activities involved in developing components of a weapons system. This type of display can be useful for conveying information about the program to those involved in its review or those charged with its day-to-day management.

From this example, we can see that as of late March, the design, fabrication, and assembly of the payload are ahead of schedule, [A].

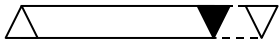
Symbol	Meaning
	Planned activity schedule
	Status of activity
	Forecasted completion behind schedule
	Forecasted completion ahead of schedule

Figure 5-1. Example Gantt Chart Symbols

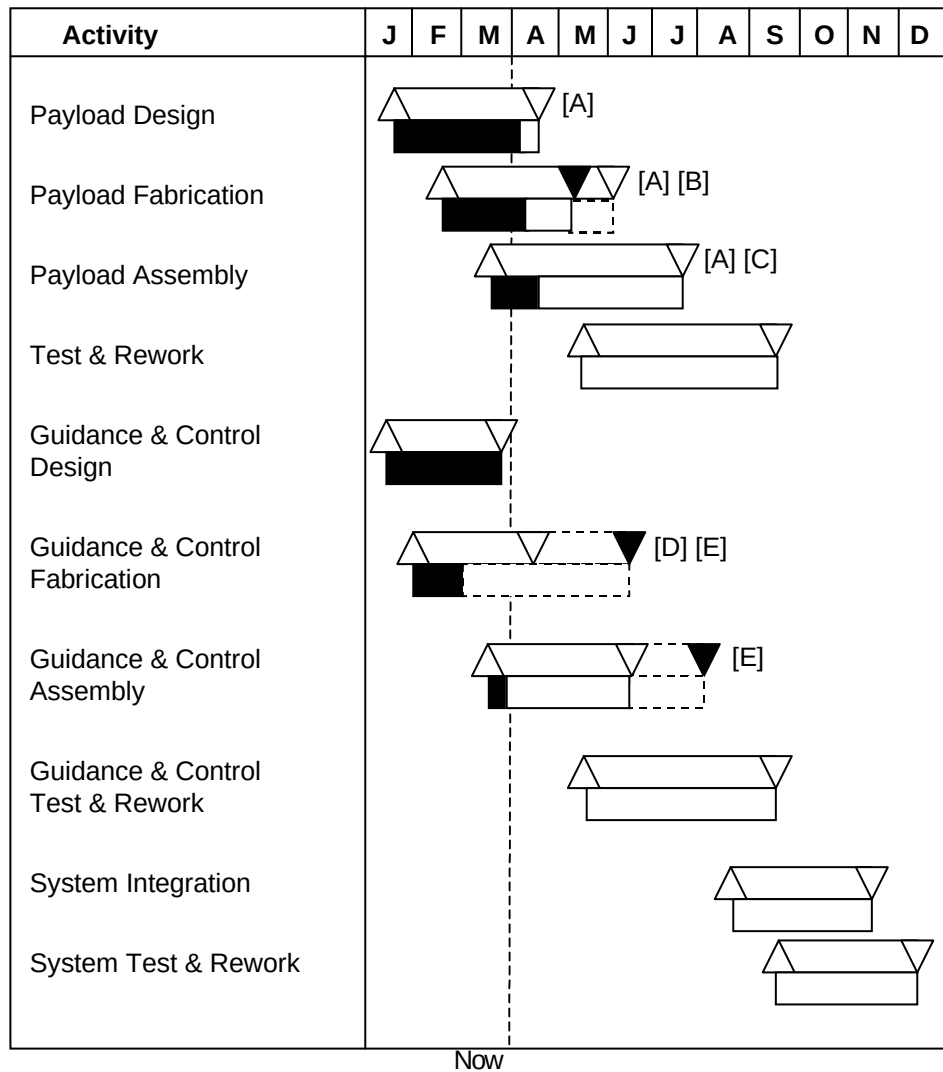


Figure 5-2. Example Gantt Chart

Based on this information, and an analysis of the activities, the PM has revised the planned completion date for the payload fabrication, [B]. In analyzing the current status, the PM has determined that much of the work in payload assembly will have to be done toward the end of the planned activity period. (In other words, the work is not uniformly distributed throughout the period.) Thus, even though this activity is ahead of schedule now, the PM has decided not to revise the planned completion date for assembly and test, [C]. This Gantt chart also shows that development of the

guidance and control subsystem is not going as well as planned. As of late-March, the fabrication is well behind schedule, [D]. After reviewing the progress and remaining work, the PM has slipped the planned completion dates for the fabrication and assembly activities, [E]. They believe that it is too early to revise the planned completion dates for test and rework, and the system integration and test activities. However, the slippage already experienced should serve as a warning that this entire development effort may be in trouble and will require close monitoring.

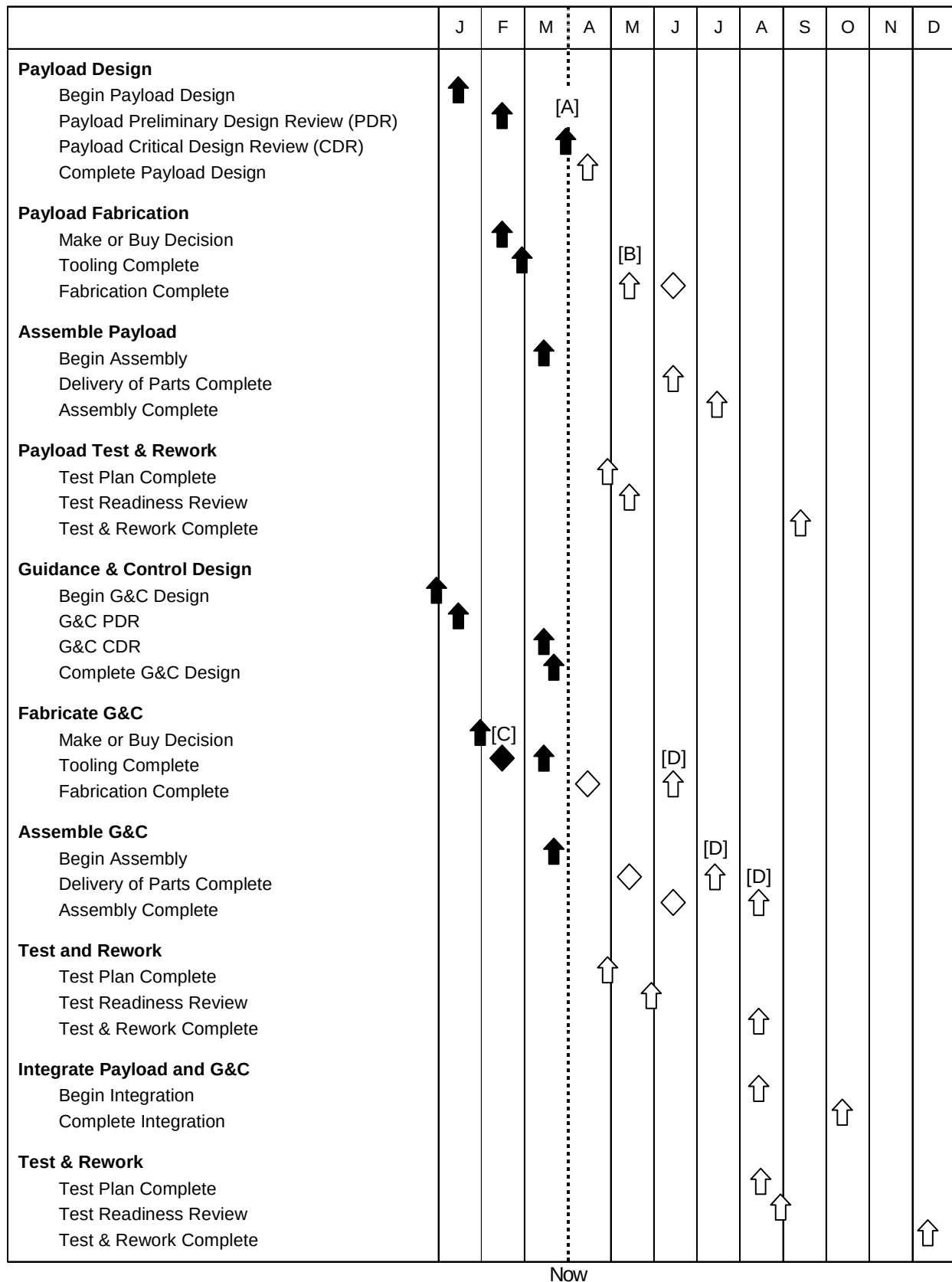
While the Gantt chart focuses on activities and their duration, the milestone chart focuses on planned significant events scheduled to occur at specific times in the program. Such events could be the initiation or completion of a particularly important or critical activity, equipment deliveries, reviews, or approval dates. Like the Gantt chart, the milestone chart uses symbols imposed on a calendar to provide information about planned and actual completion dates and any revisions to the milestone schedule. There is no standard set of symbols for milestone charts. Figure 5-3 shows the symbols prescribed for reporting milestone information within the Air Force Material Command. Different scheduling software will often use unique symbols.

The important thing is that the symbols be clearly defined and consistently applied.

Figure 5-4 shows an example milestone chart for the program described in the Gantt chart in Figure 5-2. Note that events displayed correspond to the beginning of some activities and the completion of all of them. Other events displayed represent important occurrences and key decision points within each of the activities, e.g., preliminary and critical design reviews, “make or buy” decision, etc. In this example, we see that as of late-March payload design has progressed on schedule, [A], and that planned completion date for fabrication has been revised ahead of the original schedule, [B]. As discussed in the

Standard symbols have been adapted for Air Force milestone schedules. The most common symbols used and their meanings are shown below.		
Basic Symbol		Meaning
		Schedule Completion
		Actual Completion
		Previous Scheduled Completion—Still in Future
		Previous Scheduled Completion—Date Passed
Representative Uses		Meaning
		Anticipated Slip—Rescheduled Completion
		Actual Slip—Rescheduled Completion
		Actual Slip—Actual Completion
		Actual Completion Ahead of Schedule
		Time Span Action
		Continuous Action

Figure 5-3. Example Milestone Chart Symbols



Now

Figure 5-4. Example Milestone Chart

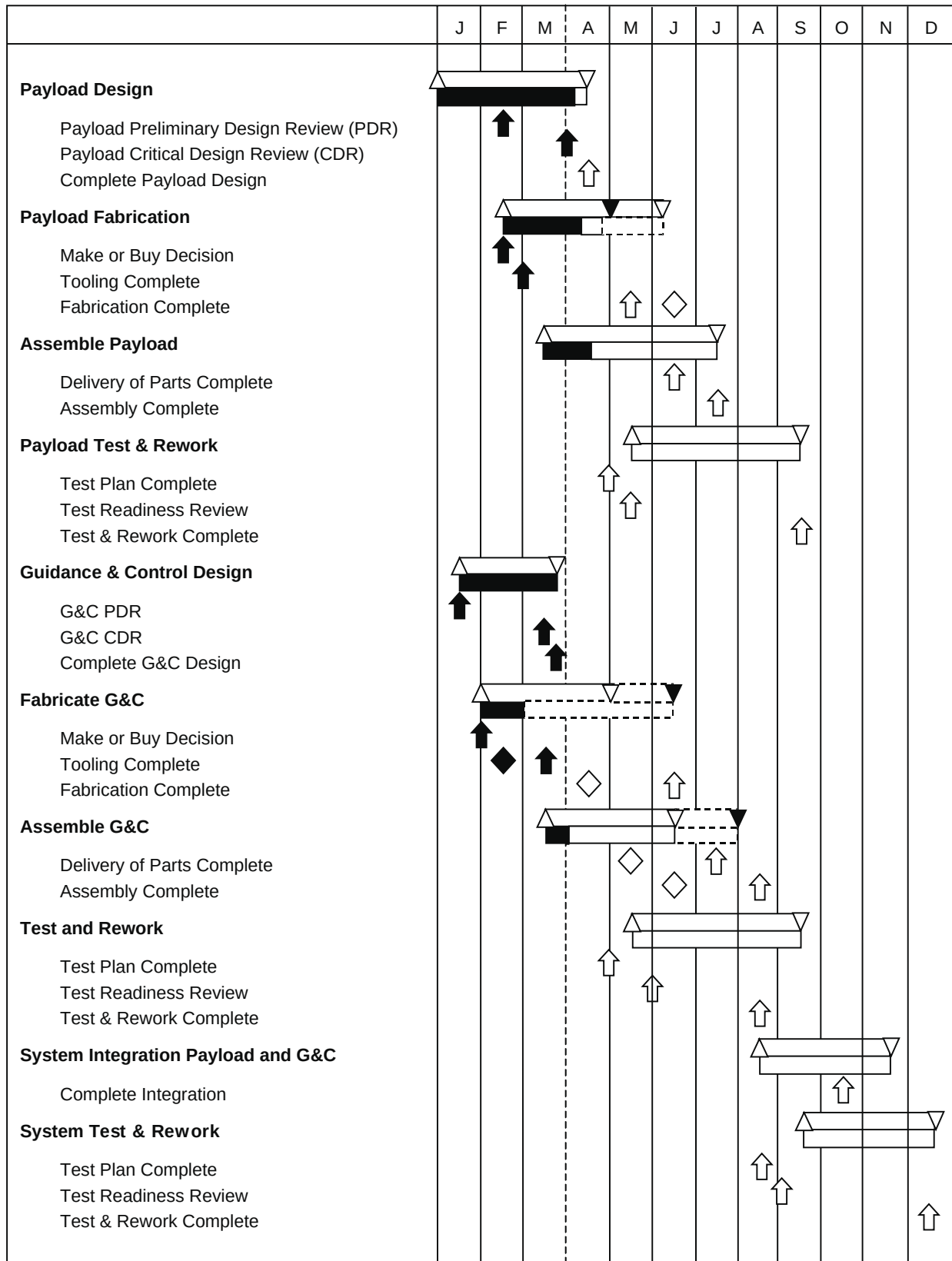


Figure 5-5. Example Combination Chart

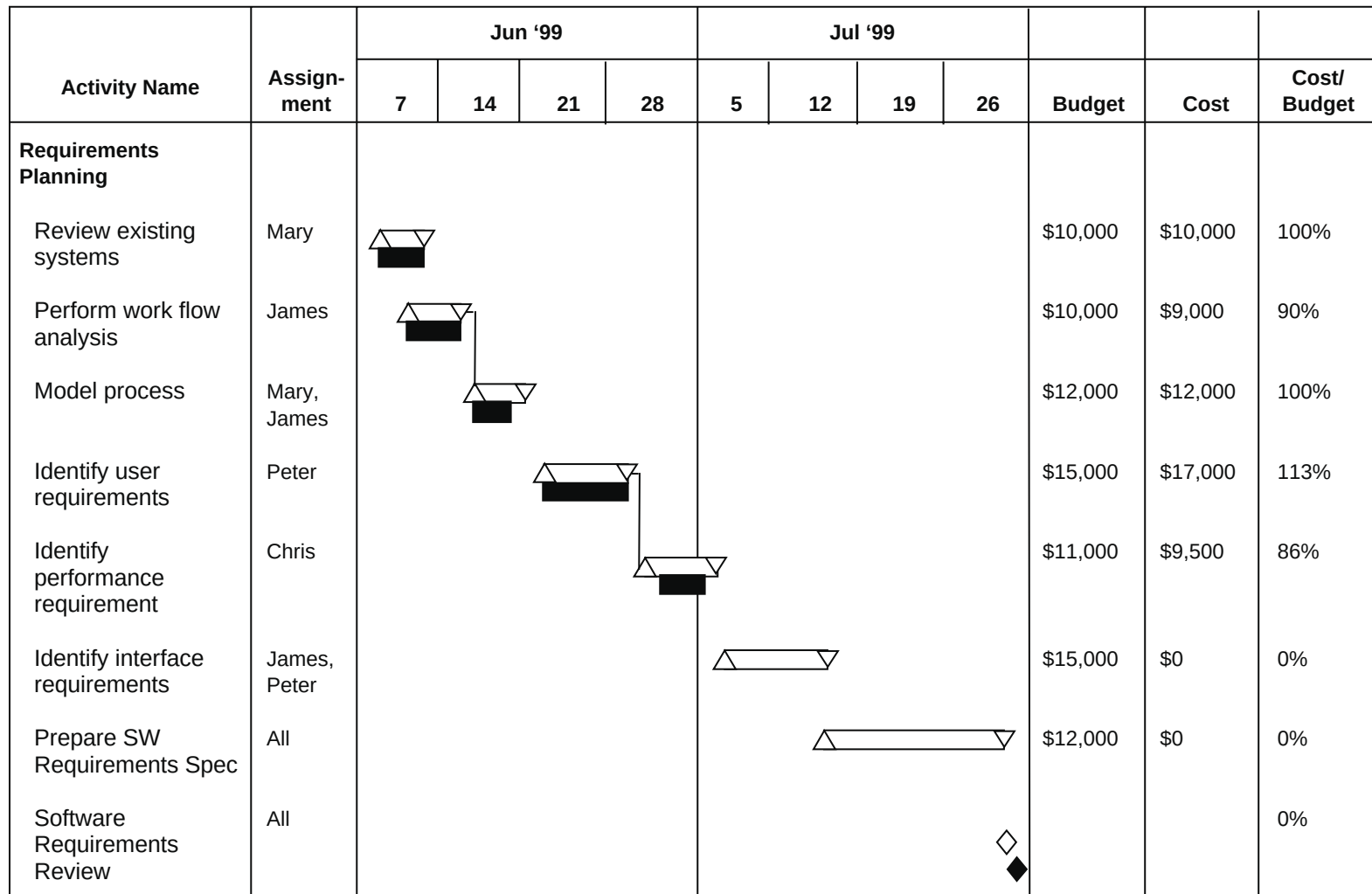


Figure 5-6. Gantt Chart with Amplifying Information

As discussed in the Gantt chart example, there are problems in the fabrication of the guidance and control subsystem. One of the events selected as a milestone was the completion of the tooling necessary for fabrication. From the example, we see that this event experienced an actual slip of approximately one month, [C]; this, in turn, has caused the Program Manager to revise the scheduled completion dates for fabrication, parts delivery, and assembly, [D].

Managers rarely use pure Gantt or milestone charts. Normally they integrate the information from these charts and display it in a combination chart. Such a chart can be useful in displaying the planned and actual duration of activities using the Gantt chart symbols and in monitoring the progress for completing key events in these activities using the milestone symbols. Figure 5-5 is a combination chart showing the activities and events described in Figures 5-2 and 5-4.

Whereas the simple Gantt, milestone, or combination charts may be suitable for reporting program status, most managers need additional information to plan, monitor, and control activities. New software applications increase the utility of these charts by making it easy to add information, such as budget, cost, resources, etc.

Today's programs use databases to store related schedule information and then allow users to filter, sort, and display information in a variety of ways. They also allow users to tailor the software to their needs by adding customized information to the database. Figure 5-6 shows how to display the relationship of one activity with another by drawing lines between related activities. The *Budget* column, in which the manager enters the budgeted cost for the

activity, is a standard feature of the particular program used to create this Gantt chart.¹ *The Assignment, Cost, and Cost/Budget* ratio columns are not standard features but were added to the database to demonstrate how the charts may be customized to meet individual needs. Note that the user may create computation fields, such as the percentage and totals fields shown in the figure.

5.2 CONSTRUCTING GANTT AND MILESTONE CHARTS

Gantt and milestone charts are relatively easy to construct when compared to the complexity of network charts. The first step is to decide the level at which the project is to be planned, tracked, and reported. This decision should consider such things as the needs of the entire project team, and the degree of risk associated with the various program activities. Most likely there will be a need to manage and track at a low level and report at a higher level. Current scheduling software has the capability to handle activities at various program levels allowing insight and management at the lower levels and permitting roll up of information at higher levels for reporting purposes. To accomplish this, charts must be developed in a logical and consistent manner.

The next step in constructing the charts is the identification of activities and milestones to be displayed, tracked, and monitored. The WBS should be used as the primary source for this identification. If a WBS is not available, or if it does not go down to the necessary level, additional planning must be done to clearly define and identify activities to be managed, tracked, and reported. Other sources for identifying activities and events include

the Acquisition Strategy, the Acquisition Program Baseline, the Risk Management Plan, and the Integrated Management Plan, and the Integrated Management Plan.

5.3 GANTT AND MILESTONE CHART ADVANTAGES AND DISADVANTAGES

Gantt and milestone (or combination) charts provide a simple, effective means to present project information, and a way to monitor and control smaller projects. Using these charts as scheduling tools has many advantages, but also limitations that should be understood. These pros and cons are presented below. Evolving scheduling software includes features that overcome some of the shortcomings to varying degrees.

5.3.1 Advantages

- (1) Simple to prepare and update,
- (2) Information portrayed in easily understood format,
- (3) Relatively inexpensive to prepare using software tools,
- (4) Relate activities and calendar dates,
- (5) Easy to roll up information into summary form,
- (6) Useful first step for preparation of more complex type schedules
- (7) Reliable estimates can be developed when the work is repetitive and when the product is easy to measure quantitatively.

5.3.2 Disadvantages

- (1) Difficult to use for detailed schedule analysis
- (2) Do not show the effects of late or early activity starts
- (3) Do not represent dependencies among activities as well as other scheduling methods
- (4) Do not reflect the uncertainty in the planned activity duration or event date
- (5) Only as reliable as the estimates on which they are based; looking at the chart doesn't indicate which estimates are the most reliable
- (6) Do not allow quick or easy exploration of the consequences of alternative actions.

5.4 HOW AND WHEN GANTT AND MILESTONE CHARTS ARE EMPLOYED

Gantt and milestone charts are best used for displaying the planned activities and events of a project and the progress in meeting them. This makes them very useful for presenting schedule and program status information in a concise simple format at such things as program or activity reviews.

Because of its simplicity and ease of interpretation, it is a particularly good tool for communicating to higher management when information must be presented quickly and efficiently. These charts may

also be sufficient for management and control of simple projects. However, they have limited utility for managing more complex projects, since they do not easily capture interrelationships among activities and events or reflect the uncertainty associated with time and resource estimates. Generally, they do not provide the level of information necessary for the effective monitoring and control of such projects.

5.5 SUMMARY

As scheduling tools, Gantt and milestone charts provide a simple and effective means for displaying actual versus planned progress of a program and for showing schedule changes that have occurred. The major drawback of Gantt and milestone charts is the limited degree of detail and dependency information they can portray. However, recently developed software scheduling applications now make it possible to show more of the relationships among project activities and events.

ENDNOTES

- ¹ This figure is an adaptation of sample charts from Fast Track Schedule sample charts.

6

NETWORK SCHEDULING

6.1 DESCRIPTION

Driven by the increase in project complexity, managers developed the need for better schedule and control methods than those provided by Gantt and milestone charts. The shortcomings of these charts gave rise to network scheduling. Over time, different applications of network theory were developed to address the needs of managers. Today, essentially three networking techniques are in use: the Program Evaluation and Review Technique (PERT); the Critical Path Method (CPM) [these two techniques are also known as Arrow Diagram Methods (ADM)] and the Precedence Diagram Method (PDM). Each is discussed later in this chapter.

All of these techniques provide the manager with powerful tools to plan, analyze, monitor, and control the project and to manage the resources necessary to accomplish project tasks. They can help the manager answer the following questions:

- When is each activity or task of the program scheduled to begin and end?
- Which activities must be finished on time to avoid missing the scheduled program completion date?
- Can resources be shifted to critical parts of the program (those that must be completed on time) from non-critical parts (those that can be delayed) without affect-

ing the overall scheduled completion date for the program?

- Among program tasks, where should management efforts be concentrated at any particular time?

Networks are a graphical portrayal of the activities and events of a project. They show how each activity relates to others in the project, the sequence of activities, and the need to perform some tasks before others. Figure 4-3 is an example of an ADM network schedule. Networks also facilitate the determination of the impact of early or late starts or finishes, provide information about the allocation of resources, and allow managers to do “what if” analyses. With this information, managers may view the status of the plan, analyze progress, and evaluate alternatives.

To apply these networking techniques, the following conditions must exist:

- All program activities must be clearly defined, including identifiable start and completion points.
- A logic diagram showing the sequence and interrelationships of activities must be developed.
- The time to complete each activity must be estimated as accurately as possible.

Accomplishing these things may require considerable effort and the involvement of people familiar with the overall project and those responsible for executing various groups of activities. This up-front effort provides an understanding of project requirements and early identification of potential problem areas.

6.1.1 PERT

In 1958, the U.S. Navy introduced the concept of network scheduling techniques by developing PERT as a management control system for the development of the Polaris missile program. The focus of PERT was to give managers the means to plan and control processes and activities so the project could be completed within the specified time period. The Polaris program involved 250 prime contractors, more than 9,000 subcontractors, and hundreds of thousands of tasks.

PERT was introduced as an event-oriented, probabilistic technique to increase a PM's control in projects where time was the critical factor and time estimates were difficult to make with confidence. The events used in this technique represent the start and finish of the activities. PERT uses three time estimates for each activity: optimistic, pessimistic, and most likely. From these estimates, an expected time is calculated based on a beta probability distribution for each activity. The developers of PERT chose the beta probability distribution because it could accommodate nonsymmetrical situations. They assumed that the probability of an estimate being too optimistic would not be equal to the probability that the same estimate would be too pessimistic. That is, if

estimated times could be compared against actual completion times in a number of cases, the variation would look like the curve in Figure 6-1.

The expected time, t is the weighted average, or mean time, for an activity based on the beta distribution and is determined from the following formula:

$$t = \frac{a + 4m + b}{6}$$

Using the expected times and other statistical properties of the beta distribution for each activity, it is possible to determine an expected time for completion of the project and the likelihood (probability) that this expected completion time will be met. It is also possible to determine the critical path for the project—the most time-consuming path through the network activities and events to project completion. Any delay on this path will delay the completion of the project.

PERT is most useful when it is difficult to either accurately estimate the time required for project activities or to determine the percentage of work accomplished within an activity. The percentage of work accomplished can be especially important when analyzing the adequacy of resources applied to an activity. Projects best suited for PERT are one-of-a-kind complex programs that involve new technology or processes and research and development.

Following the success of the Polaris program, PERT became widely used throughout the systems acquisition community, to include attempts to combine it with cost data or

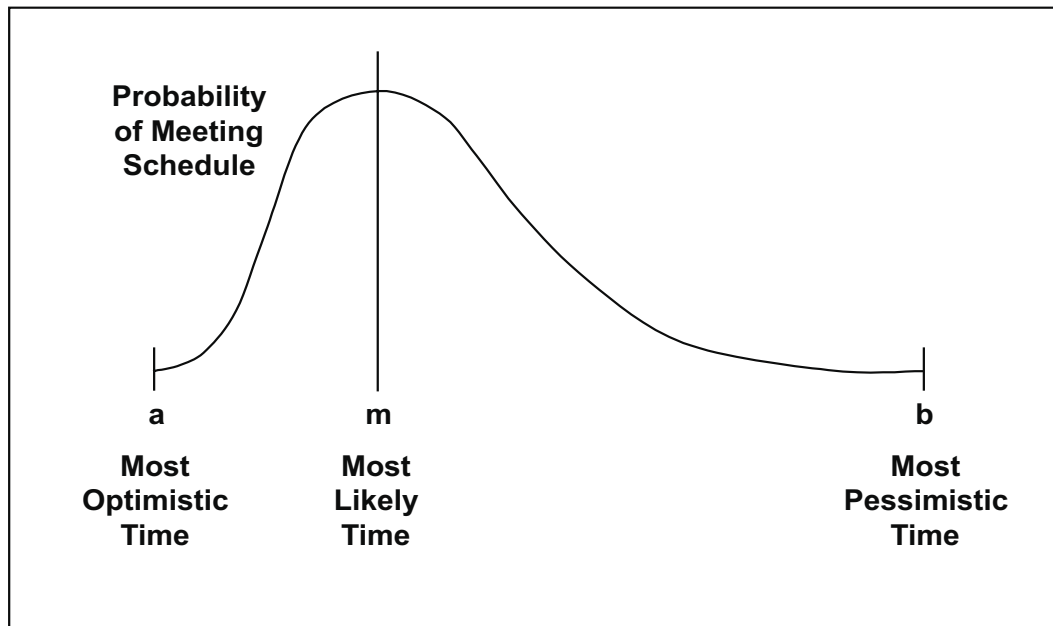


Figure 6-1. Beta Distribution with PERT Time Estimates

other non-scheduling aspects of program management. As a result, PERT became so cumbersome that the cost of maintaining it far outweighed the benefit. Consequently, the use of PERT declined and, by the 1970s, it was only occasionally employed in defense system programs. Over the last few years, it has again become relatively popular, particularly in the private sector. This resurgence is due, in part, to the development of PERT software or other networking software programs that can be run on microcomputers.

In spite of misuses that have occurred in PERT applications, the technique can be a very useful tool because it enables the manager to visualize the entire program, see interrelationships and dependencies, and recognize when delays are acceptable. Thus,

the manager is better able to assess problems as the program evolves.

6.1.2 CPM

The CPM scheduling technique was introduced at approximately the same time as PERT. It was developed by J. E. Kelly of Remington-Rand and M. R. Walker of DuPont to aid in scheduling maintenance shutdowns in chemical processing plants. Over the years, CPM has enjoyed more use than any other network scheduling technique. It is based on the concept of critical path and was designed to focus on the time and resources, particularly cost, necessary to complete the activities of a project.

Although CPM and PERT are conceptually similar, some significant differences exist,

most as a result of the type of projects best suited for each technique. As discussed earlier, PERT is better to use when there is much uncertainty and when control over time outweighs control over costs. PERT handles uncertainty of the time required to complete an activity by developing three estimates and then computing an expected time using the beta distribution. CPM is better suited for well-defined projects and activities with little uncertainty, where accurate time and resource estimates can be made, and the percentage of completion of an activity can be determined. In CPM, because of the greater certainty, a single time estimate is used. This estimate is the time planned for the activity under normal conditions; it approximates the most likely time estimate in PERT. The normal cost estimate is the cost associated with finishing the program in the normal time. A second time and cost estimate, the crash estimate, is also used in the CPM technique. The crash time estimate is the time that will be required to finish an activity if a special effort is made to reduce program time; crash cost is the cost associated with performing the effort on a crash basis so as to reduce the time to completion. This is discussed in more detail with a later example.

CPM is activity-oriented, concentrating on activity start (early start, late start) and finish times (early finish, late finish); whereas PERT is event-oriented, concentrating on early event time and late event time. The network diagrams used for CPM and PERT are essentially the same (see Figure 4-3), as are the procedures for using them. As discussed earlier, certain actions are essential to applying network scheduling techniques. The activities/events composing the project, the relationships among them, and their time estimates must be identified, and a network diagram developed. Once the diagram is

completed, the following procedures are applied:

- Complete and annotate the cumulative time required to reach each node along the paths—This will indicate the earliest time work can start on the next activity. The final number will indicate total time required to complete a particular path.
- Identify the critical path—This is the sequence of events, or route, taking the longest time to complete.
- Starting at the program completion node on the right side of the diagram, begin working backward and compute the latest time an activity can start without delaying the overall program—For example, if the total program takes 40 weeks and the final activity requires 5 weeks, this activity cannot begin later than week 35. For CPM, the difference between the latest and earliest start of an activity is the slack or float. The critical path contains no slack or float time. For PERT, the difference between the earliest event time and the latest event time at each event is the slack/float time.

The use of these procedures is illustrated in a later example.

6.1.3 PDM

PDM is an activity-oriented technique that was developed subsequent to PERT and CPM. The impetus behind this development was the need for greater flexibility in dealing with relationships and constraints between project activities.

PERT/CPM, or the arrow diagram method (ADM), essentially treats all relationships as “finish-to-start” constraints; that is, Activity A must be completed before Activity B can

begin. There are ways within PERT/CPM to circumvent this limitation, but they are cumbersome and add more complexity to the technique.

The PDM technique provides the capability to treat other types of relationships that occur in complex projects. Figure 6-2 shows examples of these types of relationships or constraints.

In addition to depicting different relationships between activities, PDM also handles time lags that would normally occur as the project progresses. Examples of

such lags are the time required for the movement of parts or components from one activity site to another, or the time involved in the reallocation of resources—people, equipment, and facilities. Figure 6-3 shows examples of constraint lags and how they can be depicted. These lags could be represented as activities in the ADM technique, but this could add needless complexity to the schedule. The use of lags in the PDM technique is much less complicated.

PDM uses the same underlying principles as the other networking techniques: clearly defined activities, accurate time estimates,

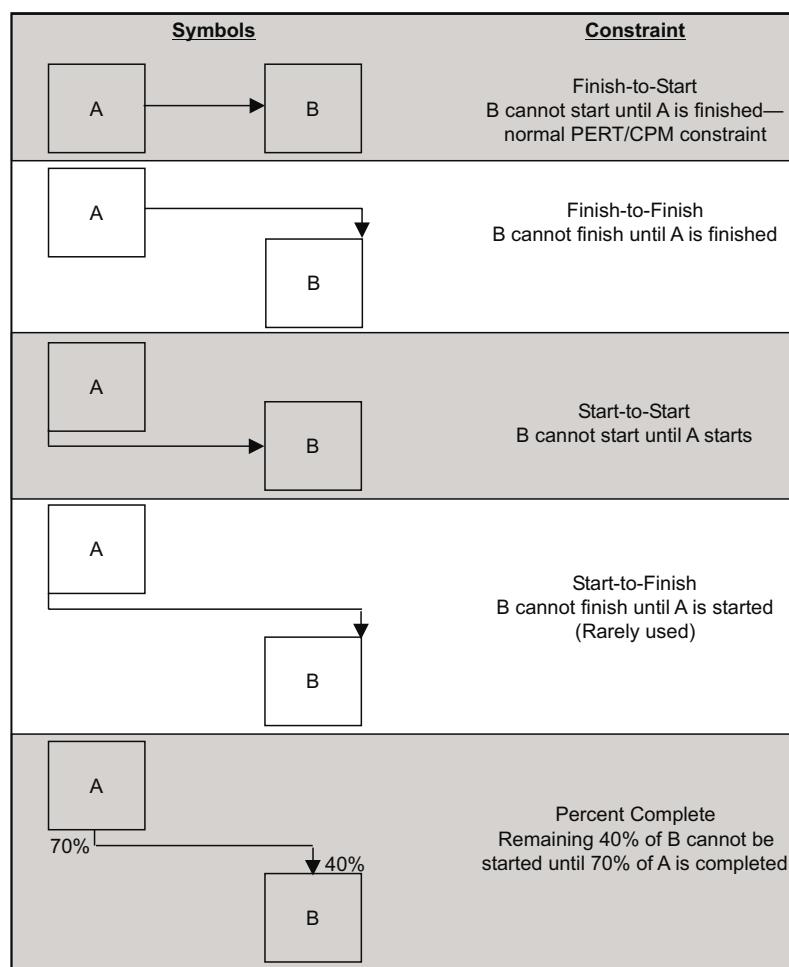


Figure 6-2. Example PDM Relationships/Constraints

critical path, etc. The difference between PERT/CPM (ADM) and PDM is in the way the network is portrayed. In PERT/CPM, the network nodes represent the events associated with activities (i.e., the beginning and end of activities), and the connecting lines represent the activities and the relationship/constraints. Activity time and resource estimates are normally shown on the

lines. In PDM, the nodes represent the estimates, early and late start and finish dates, and other appropriate information are normally shown in the boxes. Figure 6-4 is an example of an activity node. The lines connecting the nodes represent the relationships between the activities, e.g., finish-to-start, start-to-start, etc. The use of PDM is demonstrated in a later example.

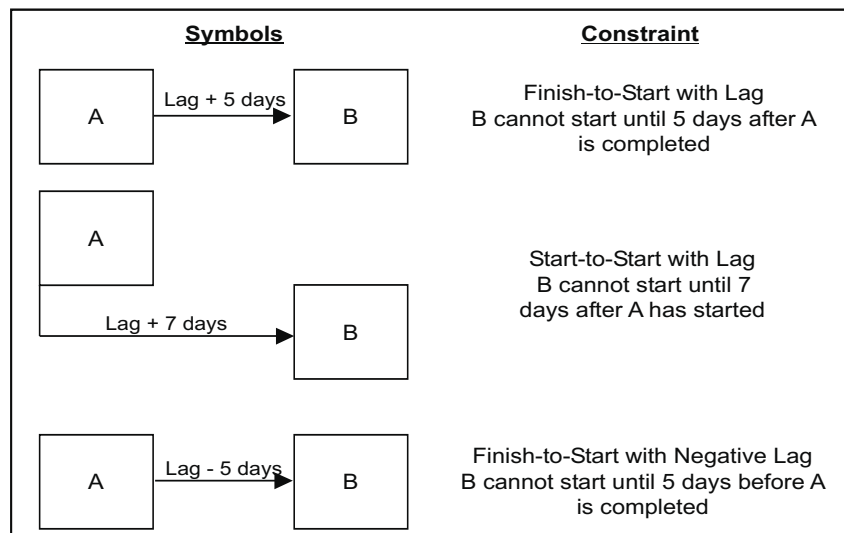


Figure 6-3. Example PDM Constraints with Lag Time

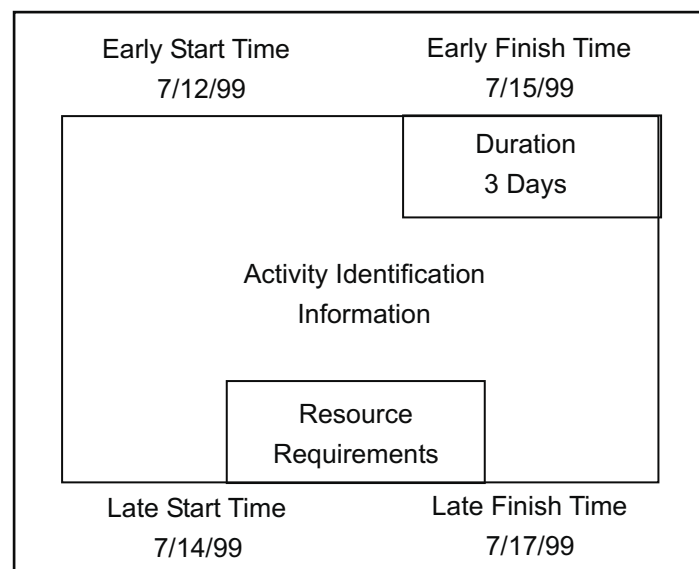


Figure 6-4. Example PDM Activity Node

6.2 NETWORK SCHEDULING ADVANTAGES AND DISADVANTAGES

Network scheduling techniques provide the mechanisms necessary to conduct a systematic, disciplined, and thorough review of what will be required to conduct and complete a project. Such an approach is essential for large, complex projects and is also useful in managing smaller, less complicated projects. The advantages and disadvantages of these techniques are identified below.

6.2.1 ADVANTAGES

- Provide graphical portrayal of project activities and relationships/constraints
- Force communications among team members in identifying activities
- Organize what would otherwise be confusing material, making it easier for managers to make tradeoffs and develop alternative plans
- Provide capabilities to evaluate progress and control project
- Allow managers to predict shortages and act on them early
- Once prepared, permit easy update and rework
- Give managers more control over activities/events and schedules
- Facilitate “what if” exercises
- Provide the basis for Gantt and milestone chart information

- Show resources associated with activities and time.

6.2.2 DISADVANTAGES

- Network construction can be difficult and time consuming.
- Only as sound as the activity time and resource estimates.
- Sometimes difficult to portray graphically—too many lines, nodes and intersections.
- Not particularly good for conveying information in briefings/reviews.
- Complex networks, once sketched out on a large wall chart, tend to become the focus of management attention when, in fact, a manager should be paying attention to factors not on the chart, such as management/labor relations.

6.3 HOW AND WHEN NETWORK SCHEDULES ARE EMPLOYED

Network scheduling techniques can be very useful in complex projects that involve new technologies or processes and that are not repetitive, such as production. They are not particularly easy to use for presentations because of their complexity; however, they can be used as the basis for other scheduling techniques that are more suitable for presentation of information, i.e., Gantt or milestone charts.

Government managers may not use network techniques in the day-to-day management of their programs. However, they should have an understanding of the techniques to ensure that contractors are using them when appropriate.

The different types of network scheduling techniques have many similarities. However, each of them provides different types of information that can be useful to managers in evaluating progress, developing alternatives, and managing the allocation of resources within their projects. The following examples show the types of information resulting from each technique and how managers may use them.

6.3.1 PERT EXAMPLE

Figure 6-5 shows a PERT network for a project containing 8 activities (A-H), with the nodes 1-7 representing the beginning and end of the activities. The three time estimates discussed earlier in this chapter are shown for each activity. For example, for Activity A, the time estimates are optimistic time=1 week, most likely time=2 weeks, and pessimistic time=3 weeks. The expected time estimate for each activity, t , as derived from the formula associated with Figure 6-1, is also shown. From this information, the project critical path can be computed by adding the time estimates along all paths leading to project completion. In this example, the critical path is determined as follows:

Path A-B-E-H=2+3+2+4=11 weeks

Path A-C-F-H=2+4+3+4=13 weeks

Path A-D-G-H=2+8+9+4=23 weeks

Thus, path A-D-G-H is the critical path since it requires the greatest time. Any delay along this path will cause a delay in project completion. The other paths are shorter completion. The other paths are shorter than the critical path and, therefore, contain activities that can be completed before they are required. Therefore, delays along these paths may not result in delays in project completion. In the above example, critical path activities, D and G, will require 17 weeks to complete. On path A-B-E-H, activities B and E will require 5 weeks to complete. Thus, there will be 12 weeks of slack along that path. Actually, this slack is only along path B, E since A and H are on the critical path. Likewise path C-F has 10 weeks of slack time. This concept of slack time, sometimes called float time or path slack/float, is important because it allows managers to reschedule activities not on the critical path to use resources efficiently.

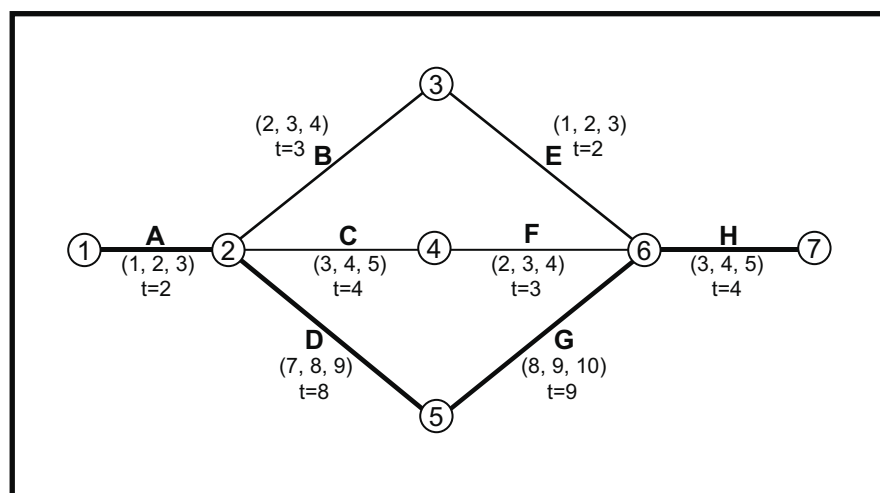


Figure 6-5. PERT Example

The following description of how slack time is computed is intended to illustrate the concept that managers can use it to their advantage. Fortunately, software programs compute slack time and managers do not have to make these calculations.

Slack time should be computed for each activity in the network. One way of doing this is by comparing the earliest time an activity can begin, T_E , to the latest time the activity can begin, T_L . The difference is the activity slack time. For all activities on the critical path, T_E and T_L have the same value. To determine the values of T_E and T_L for each activity, start with the node representing the beginning of the first activity and assign it a value of $T_E = T_L = 0$. Follow the critical path and add the activity time estimate to the value of T_E of the preceding node to get the value of T_E for the next node. For example, the node at the completion of Activity A and the beginning of Activity D has a value of $T_E = T_L = 2$. Figure 6-6 shows how T_E and T_L can be depicted on a network chart. Continue along the critical path to node 7, which has a value of $T_E = T_L = 23$, the time required to complete the project. Next, compute the values for T_E for the remaining activities and nodes not on the critical path. The value of

T_E for node 3 is the value of T_E from node 2 ($T_E = 2$) plus the duration of Activity B; for node 3, $T_E = 5$.

To determine the latest starting times for each activity, begin at the completion of the project and work backward through the activities. Since Activity H is on the critical path, its value of $T_L = 19$. Activity E is not on the critical path so its value of T_L (shown on node 3) is the difference between T_L at node 6 and the time estimate for Activity E, $T_L = 19 - 2 = 17$. The activity slack is the difference between T_E and T_L at each node. For Activity E, the slack is $T_L - T_E = 17 - 5 = 12$ weeks. This activity could start anytime between weeks 5 and 17 without any adverse impact on the critical path. Activity B is not on the critical path so its value of T_L is the difference between T_L at node 3 and the time estimate for Activity B ($17 - 3 = 14$). This is not shown at node 2, since that node also represents the start of Activity D, which is on the critical path. The slack for Activity B is $T_L - T_E = 14 - 2 = 12$. (The same approach is used to determine the slack for Activity C.) Slack is not additive along a path; it must be shared by all activities on the path. Thus, if Activity B starts at week 5 instead of week 2, Activity E would have only 9 weeks of slack available.

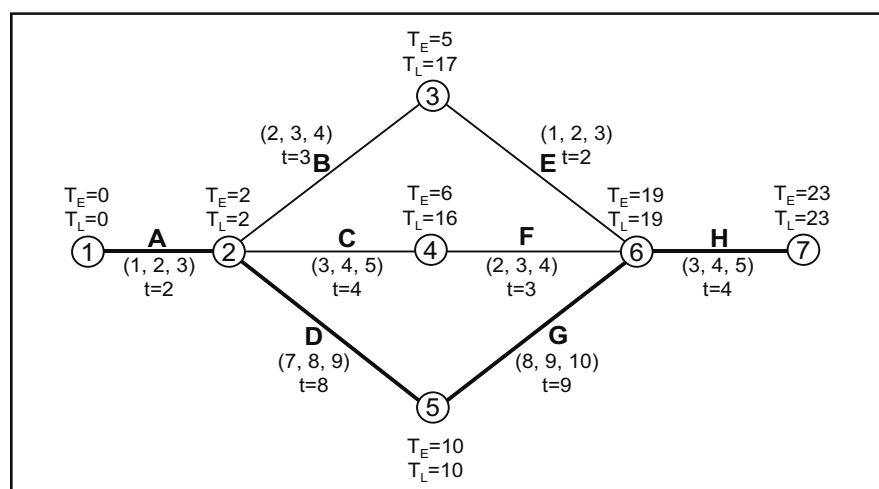


Figure 6-6. PERT Example with Slack Time

Similarly, Activities C and F have a slack of 10 weeks.

The concept of slack and T_E and T_L can be very useful to managers, providing the basis for resource allocation and also providing the means to determine the probability of meeting the project schedule. This latter topic is beyond the intended scope of this guidebook; however, a number of available books provide detailed discussion of the application of PERT techniques. (See the bibliography in Appendix D.)

6.3.2 CPM EXAMPLE

As discussed earlier, PERT and CPM are conceptually similar, in that both techniques use the same type of network structure, and the concepts of critical path and slack time. The following example will be used to illustrate basic application of the CPM technique. Figure 6-7 shows the same project as used in the PERT example, with the single time estimates for each activity. Table 6-1 shows the

time and crash estimates for each of the activities.

The critical path for the CPM approach is determined in the same way as in the PERT example. While the concept of slack time is essentially the same as in PERT, it is normally calculated in a different manner using four different values for each activity:

- Earliest time the activity can start, ES
- Earliest time the activity can finish, EF
- Latest time an activity can start, LS
- Latest time an activity can finish, LF.

To compute ES, start at the first activity and move forward through the network paths. The earliest Activity A can start is at $t=0$. The earliest that it can finish is ES plus the activity duration; thus for A, $ES=0$ and $EF=2$. The earliest start for subsequent activities is the EF of the preceding activity. For Activity

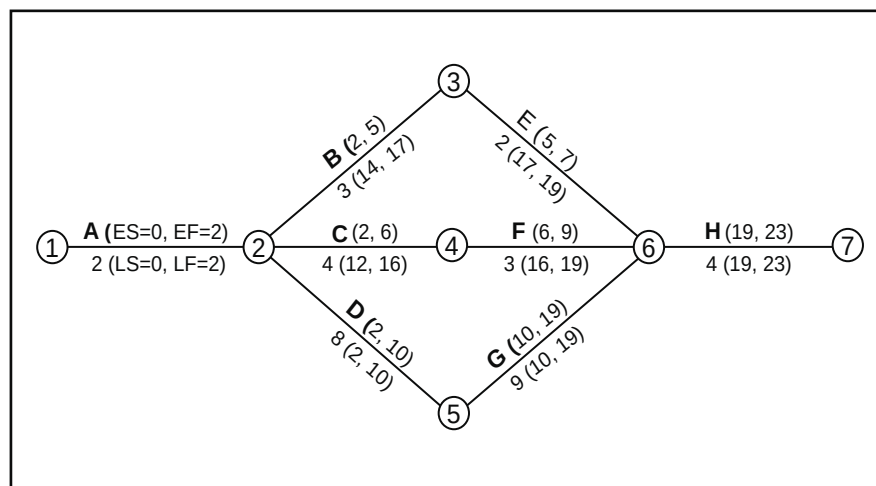


Figure 6-7 CPM Examples

B, $ES=2$. The earliest finish time for each activity is the earliest start time plus the activity duration. For Activity B this is $EF=2+3=5$. When activities converge, such as E, F, and G at node 6, the earliest starting time for the next activity is the latest value of EF of the preceding converging activities.

To compute the latest times, make a backward pass through the network, beginning with the last activity. The date to begin the pass can be either an established required date or the early finish date for the project completion. The latest starting date for the final activity is determined by subtracting the activity duration from the date used to begin the pass. For subsequent activities, the latest finish date is the same as the latest starting date for the preceding activity. In the backward pass, the value of LF for an activity that precedes a set of diverging activities in the network (activity A in the example) is the earliest of the values of LS of the diverging activities (B, C, D).

The values of ES, EF, LS, and LF for all activities are shown in Figure 6-7. With this information, one can determine the slack for each activity. Slack is determined using the following formula: $Slack=LF-EF=LS-ES$.

The relative certainty of time and resource estimates enables managers to determine the percent of work completed in each activity as the project progresses. Being able to estimate the percent of completion provides managers with the means to redistribute resources if an activity is falling behind schedule. For example, if an activity has fallen behind schedule, it is possible to estimate the work remaining and the cost of applying additional resources to complete the activity on schedule. Network scheduling techniques, particularly CPM, used on projects with relatively certain time and cost estimates can provide

managers with information to effectively manage their projects. Using percent of work completed or that is remaining on ongoing activities, they can compare the progress at a certain time with the original plan. Based on this information, they can develop revised time and cost estimates for these activities and forecast new start and completion dates for remaining activities and a new project completion date. They can then use the new forecast dates to determine action that can be taken and the appropriate resource planning and reallocation, if necessary.

The CPM technique provides managers with the means to investigate ways and impacts of speeding up, or crashing, the schedule. As part of the planning process, a set of crash estimates should be developed if possible. The estimates for this example are shown in Table 6-1.

This table shows the time and cost estimates and the crash cost per week. To crash a schedule, some key points must be considered:

- Crash only along the critical path.
- When an activity is shortened, one or more new critical paths may emerge.
- Parallel critical paths increase risk dramatically.
- Generally, least additional cost is the criterion used to select which activity to crash, but other considerations (e.g., personnel hours) could be used.

In this example, assume that the project must be crashed by 4 weeks at the least additional cost. Looking at the activities on the critical path, select the one with the lowest weekly

Table 6.1 "Crashing" the Network									
Activity Number	Time Per Activity (wks)	Critical Path		Cost (\$) Per Activity/wk		Crash Estimates (Accelerated add'l cost/week)		Min time reqd per Activity	Crash Priority
A	2	Yes	—	\$4,000	—	\$6,000	—	2	
B	3	No	—	\$2,000	—	\$600	—	3	
C	4	No	—	\$3,000	—	\$400	—	2	
D	8	Yes	—	\$5,000	—	\$3,000	—	6	1st (-2 days x \$3,000 per day) = \$6,000
E	2	No	—	\$1,500	—	\$700	—	2	
F	3	No	—	\$2,500	—	\$650	—	3	
G	9	Yes	—	\$20,000	—	\$5,000	—	7	2d (-2 days x \$5,000 per day) = \$10,000
H	4	Yes	—	\$8,500	—	\$6,000	—	3	
	35								
Note: Example same as Figure 6-7									

crash cost; in this case it is Activity D, which can be crashed from 8 to 6 weeks for an additional \$6,000. Next, crash Activity G by 2 weeks at a cost of \$10,000. Reducing both of these activities does not change the critical path.

6.3.3 PDM EXAMPLE

The PDM technique focuses on program activities and the meaning of the constraints among activities. This technique is used in many scheduling software applications, and it relies on the same concepts—critical path, slack time, etc., as the other network scheduling techniques.

Figure 6-8 shows a PDM network for a project with Activities A–I. (Assume that the unit of working time (duration) is one week.) Note that Activity B cannot start until Activity A starts, and Activity D cannot end until Activity C ends. The critical path is determined in essentially the same way as in other networks. In PDM, however, one must account for the different types of constraints. In this example, Activities B (duration=4) and D

(duration=2) will require 6 weeks to complete. However, Activity D can not be completed until Activity C is finished, which is 9 weeks (5 weeks for Activity A and 4 weeks for C). The difference between the 9 and 6 weeks (i.e. 3 weeks) must be added to the time to complete Activity D when determining the critical path. This is shown below in the parenthetical term for Path B-D-G-I. The critical path for this example is determined as follows:

Path A – C – F – I = 5 + 4 + 5 + 3 = 17 weeks

Path B–D–G–I = 4+(2+3)+2+3 = 14 weeks

Path B–E–H–I = 4+5+2+3 = 14 weeks

Thus, Path A-C-F-I is the critical path.

The slack times for the activities are determined in the same way as in the CPM technique, using earliest and latest start and finish times, ES, EF, LS, LF. Earliest times are computed by making a forward pass through the networks paths, and latest times are determined making a backward pass. Fig-

Figure 6-9 shows the PDM network with these values, using the activity format shown in Figure 6-4. The values of ES, EF, LS, and LF in Figure 6-9 represent the beginning of the unit of work time, in this case a week; e.g., ES for Activity A is the beginning of week 1, while EF is the beginning of week 6. (The beginning of week 6 corresponds to the end of week 5.) The earliest and latest finish dates for this project, Activity I, is the beginning of week 18, or the end of week 17. Using the formula for slack,

$$\text{Slack} = \text{LS} - \text{ES} = \text{LF} - \text{EF},$$

we see that on path B–D–G–I, activities B, D, and G each have a slack of 3 weeks. This slack is not additive; if Activity D starts at week 9 vice week 8, then Activity G has only 2 weeks of slack remaining. We also see that Activities B, E, and H have 3 weeks of slack

on their path. If Activity B uses 3 weeks of slack, none will be left for either path.

The above example assumes that progressing from one activity to the next requires zero time, which in most projects is unrealistic. The concept of lag time can be used to incorporate the time required to transition from one activity to another, such as machine set-up time or movement of material, parts, or components from one site to another. Lag time can be shown on the network and must be accounted for in determining critical path and values of ES, EF, LS and LF. Figure 6-10 shows that in moving from Activity D to Activity G, there will be a lag of 1 week. The figure also shows the effect of this lag time on the earliest and latest start times and on finish times. The resulting slack for Activities D and G is now 2 weeks. This example shows that the PDM

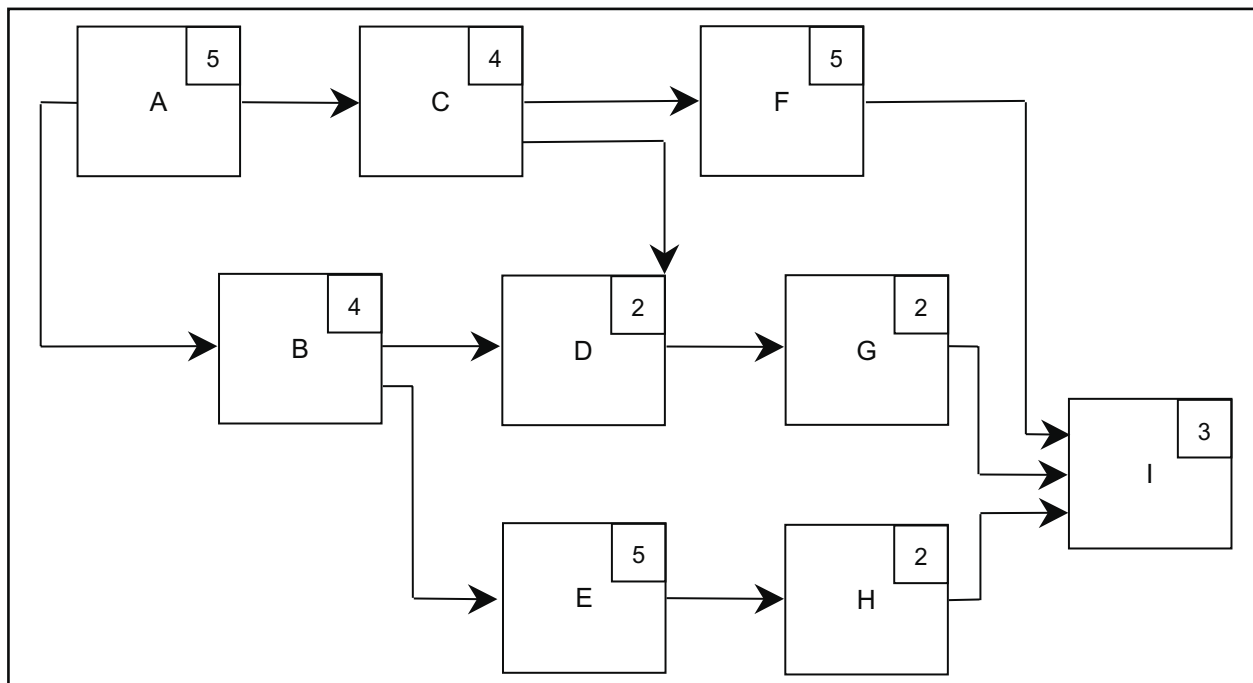


Figure 6-8. PDM Example

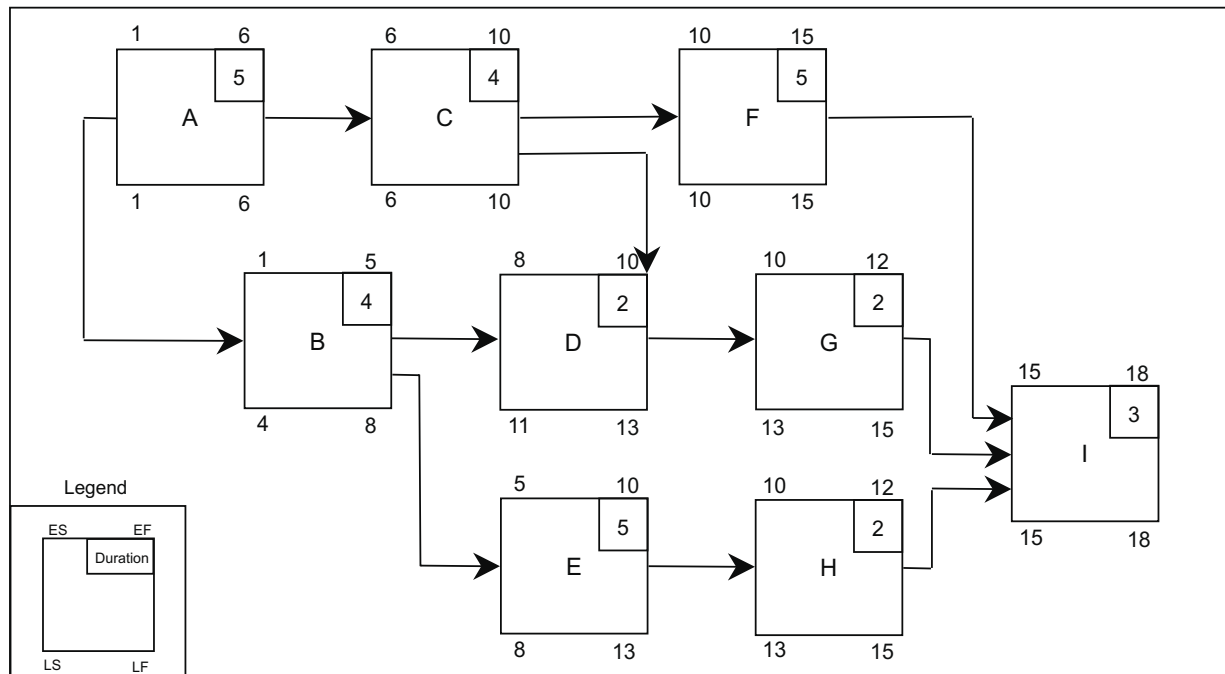


Figure 6-9. PDM Example—Early and Late Start and Finish Times

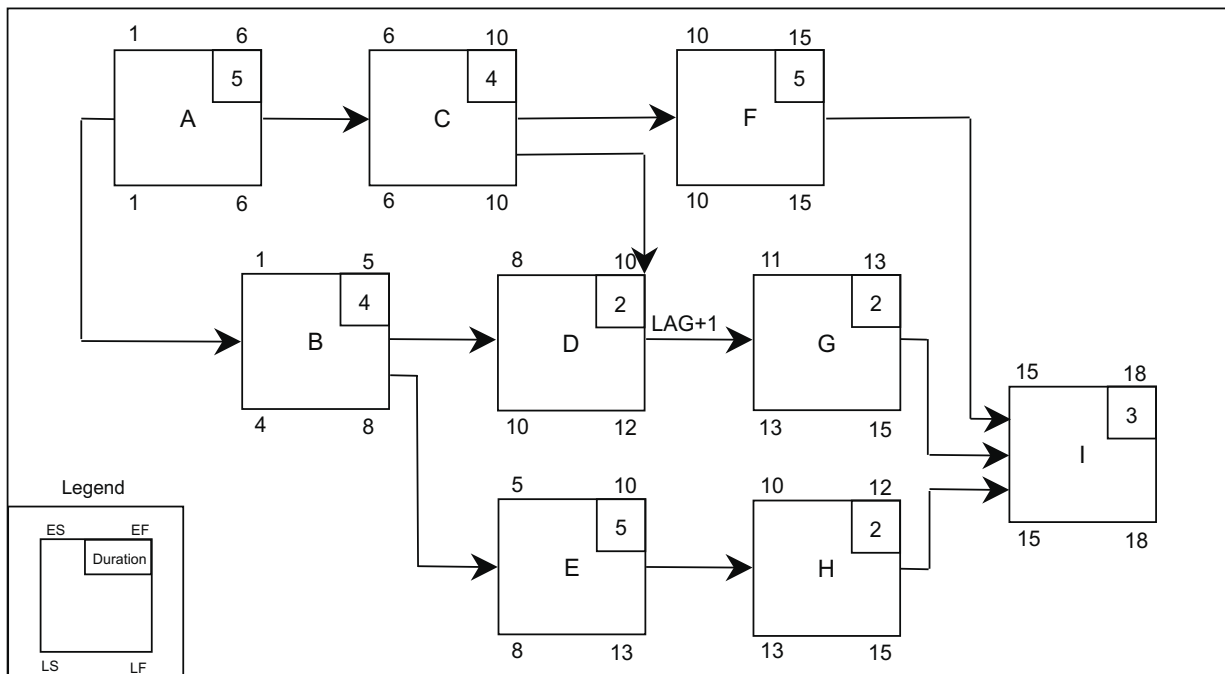


Figure 6-10. PDM Example with Lag Time

FOOTNOTES

Note: The numbering convention used in this PDM network is similar to the CPM network in Figure 6-7; it is described on page 46. Each computer scheduling program uses one (or gives a choice) of methods to relate duration to the time unit.

technique provides considerably greater flexibility in handling different types of constraints than does ADM (PERT and CPM). Consequently, it is better suited for use in complex projects, particularly those with many parallel activities and constraints other than finish-to-start.

6.4 NETWORK SCHEDULING WHEN RESOURCES ARE LIMITED

In the previous discussion, the assumption was that a new activity could start as soon as any constraints were satisfied because sufficient resources were available to perform the work. In practice, however, resources to proceed are not always available.

In those situations, Program Managers can take one or more different actions to reduce the adverse impact on the program. Those actions include:

- Adding additional resources
- Reducing the scope of the program
- Adjusting the schedule to accommodate the resource shortfall

In this section, we show how network schedules and the concepts of critical path and slack (float) can be applied to make better use of limited resources. Figure 6-11 shows a PDM network with activities A through J. Each node of the network shows the number of people required to complete the activity along with the activity duration (in weeks)

and earliest and latest start and finish times, represented as the beginning of the unit of work time (week).

To determine the adequacy of resources (people in this example), assume that each activity will start as early as possible and determine the resource requirements over time. Figure 6-12 shows the personnel loading requirements by time for the duration of the program. During week one, 11 people are required to work on activities A, B, and C. Now, let's suppose only nine people are available to work during this 11 week period. The chart shows there will not be sufficient workers during the first, fourth, and fifth weeks. There will be sufficient workers to perform the work scheduled during the second and sixth week. During the third and seventh through eleventh weeks, there will be a surplus of workers for the work scheduled. The task becomes one of rearranging the schedule so that, insofar as possible, the peaks and valleys are evened out without scheduling more work than nine people can do. In this example, this rearrangement can be accomplished quickly by hand. However, with many activities, it becomes very difficult to find the optimum answer. Fortunately, scheduling software applications are available to assist in solving the problem. Regardless of the approach used (manual or automated), the resource-leveling process is an iterative step-by-step process using a set of rules to establish the priority of the activities requiring the constrained resource, and the actions to be taken.

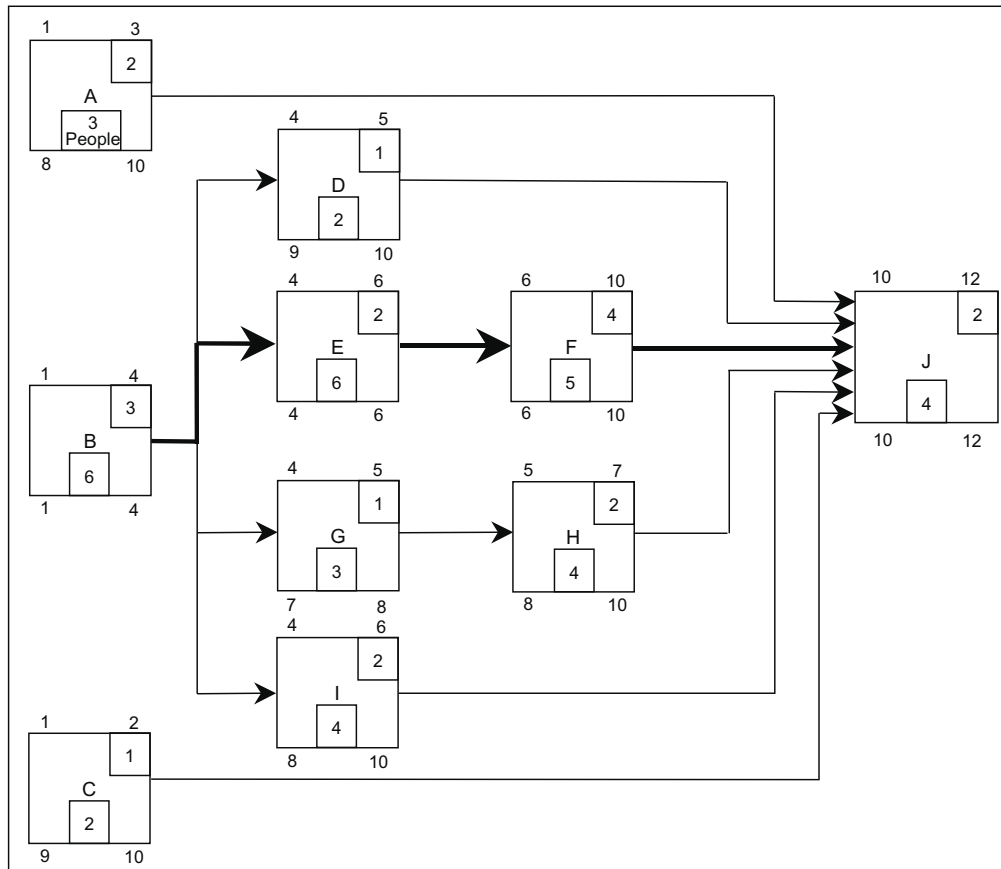


Figure 6-11. Network Schedule with Constrained Resources

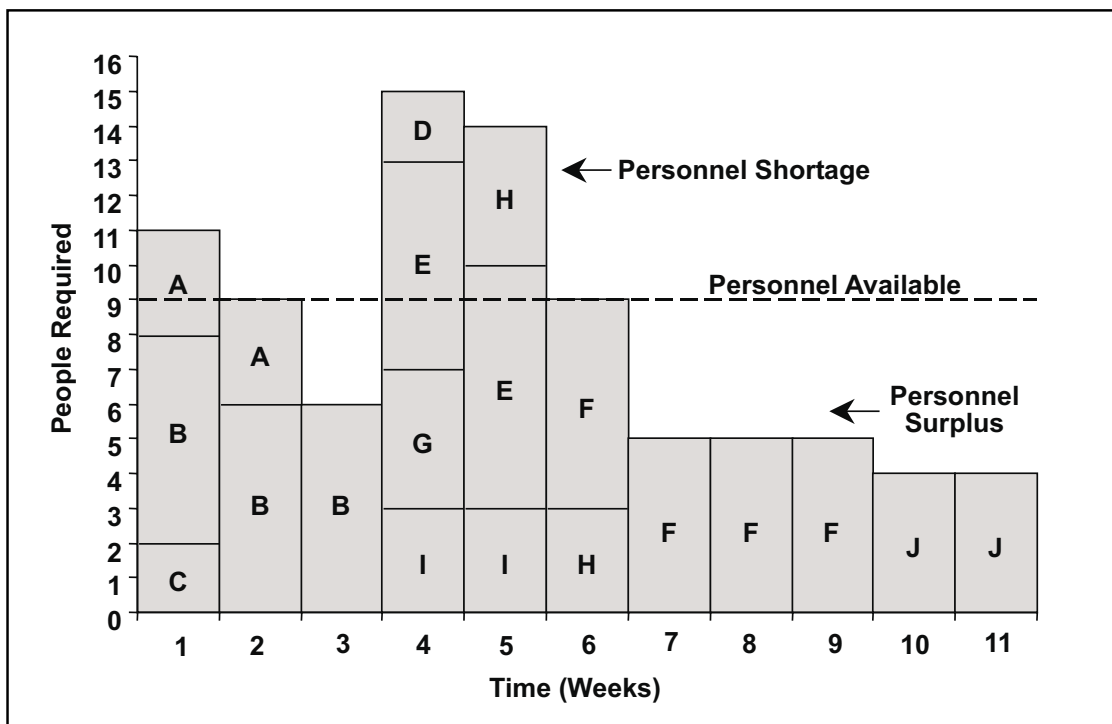


Figure 6-12. Personnel Loading Chart

As discussed earlier, the concept of float (or slack) can be useful in the efficient allocation of resources, and it should be considered in establishing the rules to be followed. The float demonstrated in earlier examples is commonly called path float. Another type of float that is particularly useful in resource allocation is free float. Free float is the slack that a single activity can experience without affecting any other activity.¹ The free float of a given activity is defined as the difference between earliest start of the succeeding activity and earliest finish of the given activity. In our example, the free float for Activity D is $FF(D) = ES(J) - EF(D) = 10 - 5 = 5$.

In this example, the approach is to find activities having the most free float and try to delay them as long as possible without delaying the entire program. By delaying the start of Activity C for 2 weeks (to the beginning of week 3), Activities A and B can begin simultaneously without exceeding the limit of nine workers. Similarly, Activities D, H, and I can be delayed, resulting in the revised personnel loading chart shown in Figure 6-13.

Figure 6-14 shows the revised schedule using lag times to reflect the delays. Note that Activity A has a start-start relationship with Activity B. The “Lag 0” constraint indicates that A should start when B starts. Any delay in starting Activity A will result in a person-

nel shortage as the project progresses. It may not always be possible to rearrange the schedule to stay within the resource constraints. In those cases, other steps, such as adding more resources or extending the schedule, will have to be taken to minimize the adverse impact on the program.

6.5 SUMMARY

Network scheduling techniques (PERT, CPM, and PDM) are much alike in providing such things as interdependencies, depth of detail, a critical path, and slack. The choice among these three techniques depends primarily on the type of program and managerial objectives. The PERT method is particularly useful if there is considerable uncertainty in program activity times and if control of the program schedule outweighs other factors. On the other hand, CPM is more appropriate when activity times can be adjusted readily and when it is important to plan an appropriate tradeoff between program time and cost. The PDM technique is best suited for complex projects with different types of relationships/constraints between activities. In reality, the proliferation of scheduling software has blurred many of the differences among network scheduling techniques as well as Gantt and milestone techniques.

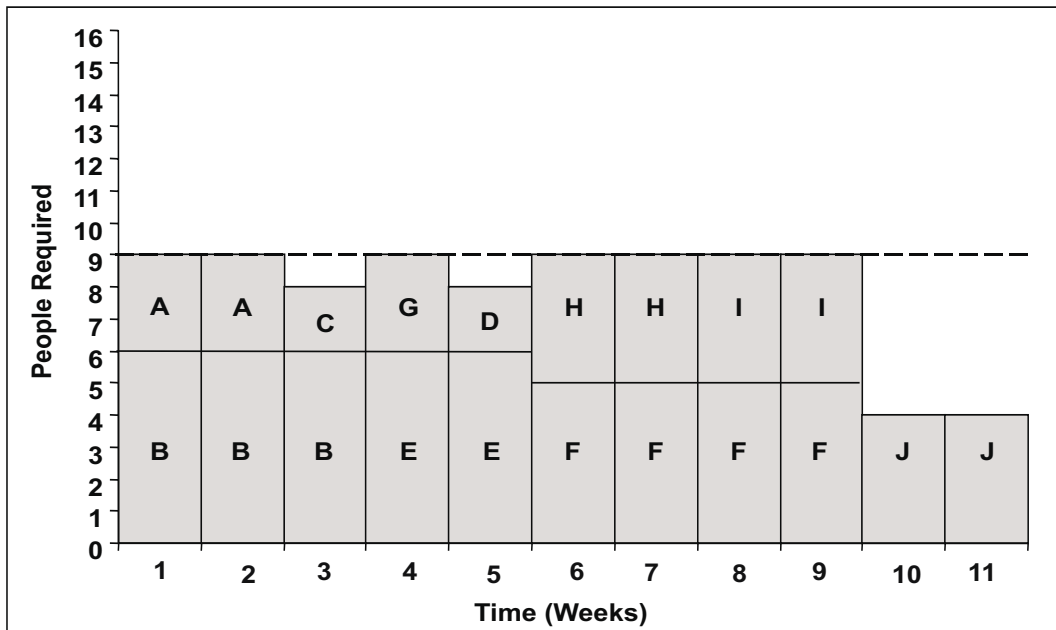
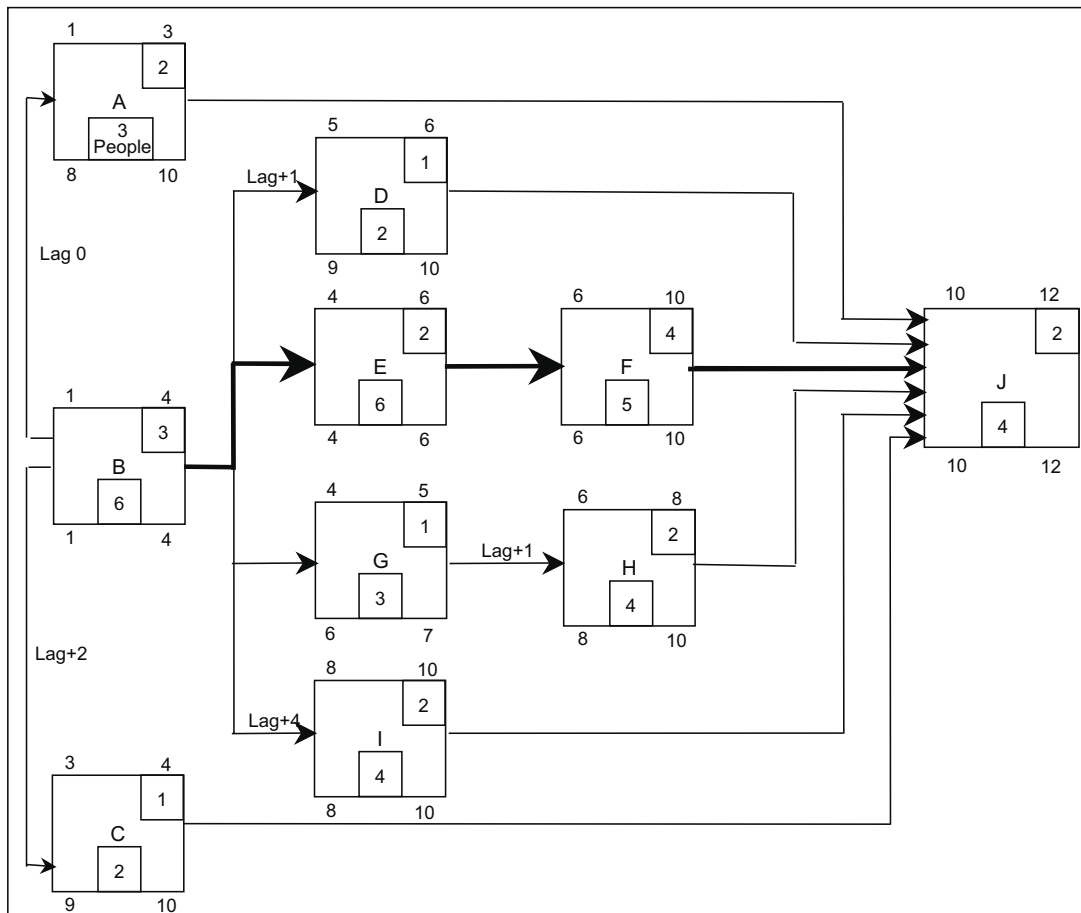


Figure 6-13. Revised Personnel Loading Chart



6-14. Revised Network Schedule with Constrained Resources

ENDNOTES

- ¹ Fleming, Bonn, and Humphreys, *Project and Production Scheduling*, Probus Publishing Co., Chicago, IL, 1987, Chapter 8.

7

PRODUCTION SCHEDULING

7.1 DESCRIPTION

The scheduling techniques discussed in the previous chapters are best suited for one-time development projects. Production scheduling, as its name implies, focuses on the planning, execution, and control of repetitive activities, such as those involved in the manufacture of several identical items using the same processes. The objective of production scheduling is to balance the materials required to produce the items with the production process and the delivery schedule. Such scheduling is essential to the efficient use of all resources and facilities involved in the manufacturing process.

While the principles of planning and scheduling are essentially the same for both situations, there are differences that should be considered. For example, in the development phase, planning and scheduling should reflect the uncertainty inherent in development of the product and processes used. Consequently, planning and scheduling should permit sufficient flexibility to allow for redesign and retest when inevitable problems arise. In production, there is less uncertainty; the design is relatively stable and the processes to be used are fairly well-defined. In general, more definitive constraints exist in production scheduling, such as quantities to be produced, required delivery dates, and capabilities and availability of production assets.

Production planning and scheduling should be very detailed. A top-level project schedule should serve as the production baseline. It should reflect the integration of activities that different organizations involved in the production process conduct—tooling, material procurement, etc. Lower tier schedules should be developed for each of the manufacturing activities, with special attention to those having potential impact on the delivery schedule, e.g., material procurement; tool design, fabrication, and prove-out; test equipment prove-out; and capital equipment procurement. Thorough planning and integration of all production process activities are essential to manage risk in the manufacturing approach. This also provides assurance that necessary resources will be available when needed, that no resources will be overloaded or completely expended during execution of any manufacturing task, and that product delivery dates are achievable.

An understanding of the production processes, to include such things as the sequence of operations, make or buy decisions, inspection methods, tooling, etc., is critical to effective production planning and scheduling. The planning and scheduling of all activities must be fully integrated and reflect a synchronized flow of events that result in product or process completion when required. The production schedule describing and integrating such things as the acquisition of required materials, fabrication flow, process times,

plant facilities to be used, and personnel skills required should be developed as early as possible in the development process and included in the manufacturing plan.

Once the planning and scheduling are complete and production begins, managers need the means to monitor progress and to identify problem areas in the process that could adversely affect the delivery schedule. A technique that is commonly used for this purpose is the Line of Balance (LOB) technique. It graphically portrays the key activities of the production plan relative to a required delivery schedule and provides a view of the progress being made in each activity. This enables managers to focus their attention on specific problem areas in the process.

Government PMs, except those associated with an activity that builds or re-builds equipment, will never be responsible for developing a production schedule. However, they should understand the process of creating one because the success of a program is very dependent upon the producer to plan, schedule, and implement a production plan.

The ensuing discussion provides a basis for understanding the fundamentals of production planning and monitoring. Most companies have tailored planning software programs to fit their needs, however the principles are the same as those used in the LOB approach. For that reason, LOB is the subject of discussion.

The LOB technique consists of four elements as described below and shown in Figure 7-1. The application and use of this technique is demonstrated in a later section of this chapter.

7.1.1 Objective Chart

An Objective Chart (Figure 7-1A) is a display of the cumulative contract delivery schedule over time. It shows cumulative units on the vertical scale and dates of delivery along the horizontal scale. It also shows actual cumulative deliveries to date.

7.1.2 Production Plan Chart

This chart (Figure 7-1B) shows the major production process activities and events (control points) that are to be monitored using this technique. It also shows the lead-time associated with each of the control points.

The more steps that are monitored, the more sensitive and more complicated the chart becomes. Generally, control points on a single chart should be limited to 50. If there are more than 50, subsidiary production plans can be used to feed the top plan. Thus, each chart can be kept simple and easy to understand. The shipping date of subsidiary charts is the point at which a subprogram must be ready to join the overall schedule.

On the production plan chart, each monitored step is numbered, left to right. Step 1 has the longest lead time; the shipping date is the highest-numbered step. When two steps are done at the same time, they are numbered from top to bottom, such as steps 8, 9, and 10. These control points can also be given symbols that show whether they involve purchased items, subcontracted parts, or parts and assemblies produced in-house. Assemblies break down into subassemblies, which break down into parts or operations. Thus, one can develop a production plan for any part or level of assembly.

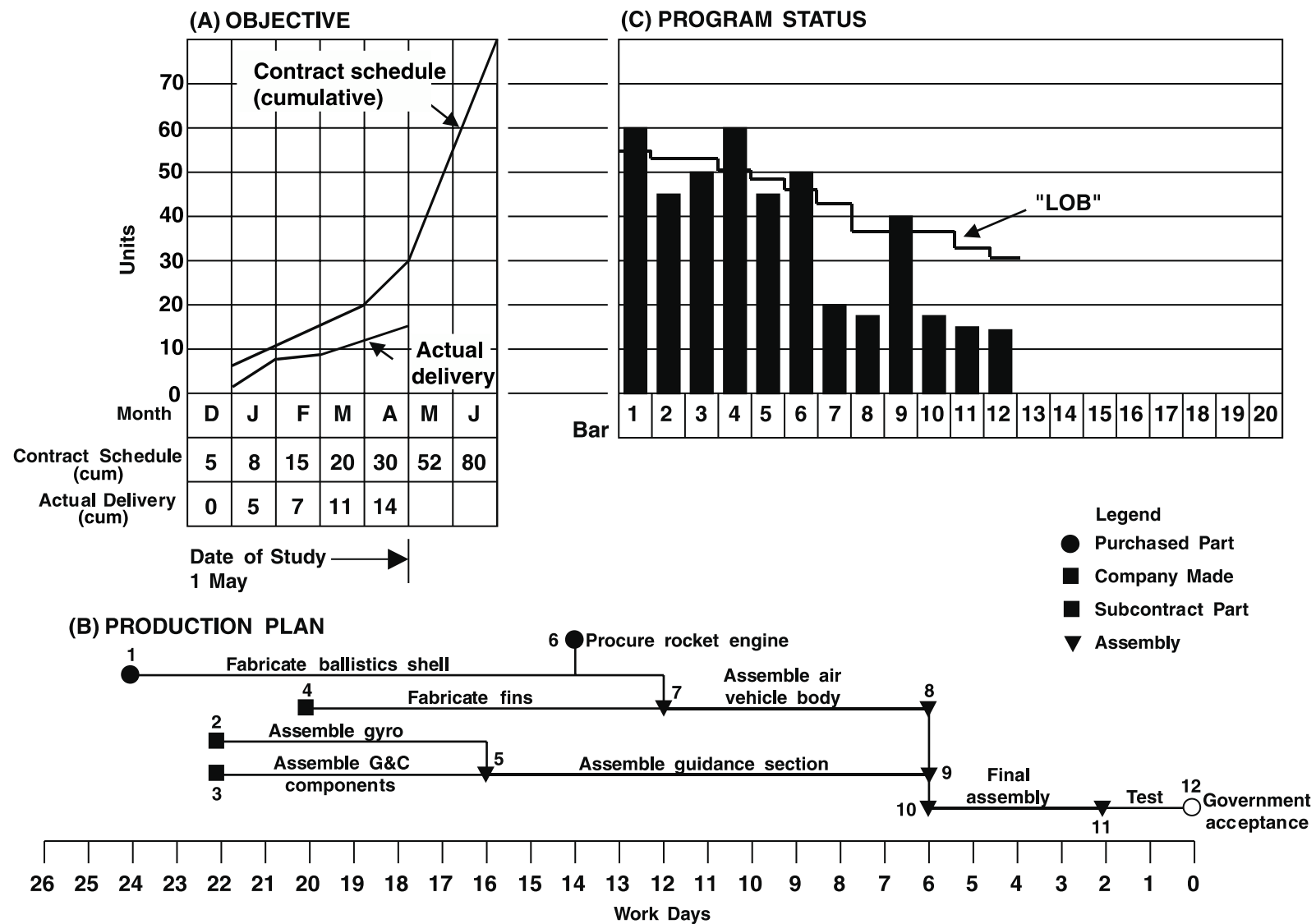


Figure 7-1. Line of Balance Technique

The production plan chart shows the interrelationships and the sequence of major steps, as well as lead times required for each step. An understanding of the manufacturing processes involved and sound judgment are required to know which step and how many steps must be monitored. Slack or float times for activities are not considered when plotting the production/lead-time chart; only the estimated time (and latest finish point) for each activity is used.

The 12 control points in the production plan chart shown in Figure 7-1B represent key tasks in manufacturing one lot of missiles. The plan indicates that control point (1), fabricate ballistics shell, must begin 24 workdays before 1 January to meet the first scheduled delivery of five units by the end of December (see the objective chart). The lead time for other control points can be related to the scheduled delivery in a similar manner. Time for in-house transfer and storage must be allowed in addition to the processing time.

7.1.3 Program Status Chart

This chart (Figure 7-1C) shows the cumulative inventory status at each control point in the process at a given time (in this case, 1 May). Looking at control point 12, we see that the government has accepted 14 units of the product. The bar for control point 9 shows that 40 units of the guidance section have been assembled, and the bar for control point 4 shows that in-house fabrication has begun on 60 fins.

The cumulative numbers of units through every control point can and should be measured monthly. Final deliveries (government acceptances) are shown month-by-month on the objective chart as actual deliveries.

7.1.4 Line of Balance

The LOB represents the number of units that should have passed through each control point (cumulatively) to satisfy the contract delivery schedule. Managers use it to analyze how the status of each control point on a given date will affect future schedules. This LOB is drawn on the Program Status Chart (Figure 7-1C) using the following procedures:

- (1) Select a control point; for example, 7.
- (2) From the production plan/lead-time chart (Figure 7-1B), determine the lead time—the time from control point 7 to the shipment point, Government Acceptance (12 workdays).
- (3) Using this number, determine the date that the unit now at control point 7 should be completed. (May 1 + 12 workdays = just over halfway through a 22-workday month.)
- (4) Find the point corresponding to this date, approximately May 17, on the contract schedule line and determine how many units scheduled for completion this represents by moving horizontally from the objective chart to the program status chart (they share the same vertical scale).
- (5) Draw a line on the program status chart (Figure 7-1C) at the level (43 units) over control point 7.
- (6) Repeat the above for each control point and connect the horizontal lines over the control points. The resulting line is the LOB, indicating the quantities of (1) units that should have passed through each control point on the date of the study or inventory (1 May) if the contract delivery schedule were being met.

The difference between the LOB and the top of the bar for each control point is the number of units behind or ahead of schedule as of 1 May. Thus, control point 12 is 16 units behind schedule, control point 9 is 5 units ahead of schedule, and control point 7 is 21 units behind schedule. The main impact of control point 7 being behind schedule will be felt in 12 workdays, which is the lead time for control point 7. As of 1 April, an insufficient number of air vehicle components (shell, fins, engine) had passed into the assembly (air vehicle body) phase. This will adversely affect final deliveries 12 workdays hence. All other control points can be analyzed in the same way.

7.2 WHEN AND HOW TO USE THE LINE OF BALANCE TECHNIQUES

7.2.1 General

The LOB technique should be considered for use in any project requiring the manufacture of a specific quantity of a product using repetitive processes. It is an effective technique for identifying those activities that require attention and possibly corrective action and can also be used for reporting the status of the manufacturing process and delivery schedule to higher management. The LOB charts should be updated on a periodic basis (weekly or monthly, depending on such factors as the size of the production run, the number of activities/control points, and the level of automated data management).

Government managers will probably not be involved with the LOB technique in the day-to-day management of their programs. However, they should have a basic understanding of the technique, the type of information it can convey, and its applicability.

7.2.2 Analysis

Using the LOB charts in Figure 7-1, management can tell at a glance how actual progress compares with planned progress. Analysis of the charts can pinpoint problem areas. Delays at control point 7 in the example may have been causing final delivery problems throughout the contract. However, the purpose of LOB analysis is not to show what caused the slippage in the shipping date, but to detect potential future problems.

In the example, the Government acceptance point is control point 12. The bar doesn't reach the LOB; therefore, deliveries are behind schedule. Control points 10 and 11 are short. However, point 9 is on schedule. Since point 10 depends on points 8 and 9, we know control point 8 is the offender. Both points 7 and 8 are short, but there are more than enough purchased items (engines) at control point 6.

What's the problem with control point 8? Trace it back to control point 7, which is seriously short. It is obvious that not having enough completed fins is holding up the whole process. Control points 2, 3 and 5 are short, but are not directly responsible for the failure to meet the delivery schedule since 9 is ahead of schedule. Nevertheless shortages at 2, 3, and 5 could soon cause problems at 9. The problem with the fins 7 should be addressed before management attention is devoted to other short operations. The overages at control points 1 and 6 may be examined from the point of view of inventory control. Updating the charts requires a good status-reporting system, which can be mechanized if the program is large and complex.

7.3 LINE OF BALANCE ADVANTAGES AND DISADVANTAGES

7.3.1 Advantages

(1) Points out problems before their impact on finished product deliveries show up, thereby allowing managers to correct problems earlier.

(2) Allows managers to see, in the middle of a contract, whether they can meet the contract schedule if they continue working as they have been.

(3) Focuses attention on those production control points where there are problems; this allows a senior manager to pinpoint responsibility for slippages.

7.3.2 Disadvantages

(1) People working on a project may not grasp what the LOB is measuring.

(2) Limited to production and/or assembly-type processes.

(3) Shows only where the problem is, not what it is.

(4) A monitoring device; not as easy to use as a planning device.

7.4 SUMMARY

The LOB is a monitoring technique that gives prior warning of problems within a continuous production process. The key is to catch problems in a production process early; otherwise, the schedule is lost. The LOB technique provides that warning.

Think of the production process as a natural gas pipeline. If a bubble of air gets into the pipeline, it will eventually be carried to the gas users, and the users will find their burners extinguished as the nonflammable air reaches them. The manager of the pipeline company or the natural gas utility doesn't want clients to suffer blowouts from air bubbles in their lines. The same holds true for the managers of a continuous production process. Waiting for problems to show up at the end of the line is a mistake. Problems need to be detected when they begin so corrections are faster, before too much damage (to cost, performance, or schedule) is done, and production schedules fall too far off contract.

To do LOB, the following is needed: (1) a contract schedule, or objective chart; (2) a production plan or lead-time chart for the production process itself; (3) control points cumulative inventories; and (4) a program status chart on which to plot LOB and the cumulative quantities of units that have passed through the control points of the assembly/production process. If the objective and program status charts are given the same vertical scale, the LOB can be plotted graphically from the former to the latter.

Remember that the shape of the LOB will change over time, especially if the production process has a beginning and an end. Remember, too, that LOB charts show where a problem is, but not necessarily why the problem exists or what the solution is.

8

TIME MANAGEMENT

In most programs, especially in DoD and defense-related industries, time is a resource that must be carefully managed. If it is not, it can become a serious constraint that can threaten the success of the program. This chapter addresses time management from two perspectives: first, as it relates to a program, and second, as it relates to the PMs use of time.

8.1 TIME MANAGEMENT AND THE PROGRAM

This section concerns three aspects of time management related to programs:

- (1) Time reserve
- (2) “Now” schedule
- (3) Value of time.

8.1.1 Time Reserve

In contractor performance measurement, much emphasis is placed on “management reserve,” the reserve budget controlled by the industry PM. What isn’t always recognized is that a time reserve is also needed in order to accommodate unknowns in the program. However, use of a time reserve should be approached with caution, because members of a program office team may be tempted to fall back on it prematurely.

Literature describing time reserve is scarce. However, there are some aspects of a time reserve that are clear.

(1) Most PMs establish a time reserve of about 10 percent. On a 40-month program, for example, a 4-month time reserve would be established.

(2) The time reserve must be held closely by the PM. Otherwise, every manager on his/her program may think “I know there’s a time reserve; therefore, I don’t really have to meet my schedule.” The PM may place this reserve under “additional system tests” or another downstream activity. The point is, it shouldn’t be visible. (A built-in safety factor between the manufacturing schedule and the delivery schedule is often used.)

(3) A tough and disciplined approach to meeting the published schedule is required from the start of a program in order to maintain the reserve and, consequently, to meet the program schedule in spite of slippages caused by the unknown unknowns (unk-unks) that inevitably arise.

8.1.2 “Now” Schedule

There is a direct relationship between time and cost for any activity. This relationship takes into account the people, resources, and method used. It also considers the efficiency achieved. Generally, the least costly schedule is the current one. Speeding up the schedule costs more; stretching out the schedule also costs more.

The sum of the direct and indirect costs gives a U-shaped total program cost curve.

The optimum schedule for implementing the program is the schedule corresponding to the minimum point on this curve. The relationship among direct, indirect, and total program cost is shown graphically in Figure 8-1.

Because schedule stability affects program costs, which may, in turn, affect technical performance, it is clear that schedule stability has a great deal to do with whether the program meets its cost and technical objectives. Unfortunately, budget constraints and other factors, like changes in quantities (items over which the PM has no control), have often been imposed on a program with the comment, "Do the best you can."

When a schedule must be revised, the superseded schedule is often discarded. If the new schedule is superseded, the process is repeated. However, there is some value in retaining an obsolete schedule.

Often, the organization causing a slip in schedule becomes a repeat offender. The principal value of retaining a former schedule lies in being able to hold the offender's feet to the fire, thus making schedule slips less palatable.

The significance of maintaining a stable schedule is becoming more widely recognized. Appendix A describes the development of a master schedule and the importance of maintaining schedule discipline.

8.1.3 Value of Time

According to the late John H. Richardson, president of Hughes Aircraft Company, "A basic reason for adopting project (or program) management, when tackling the difficult and unique tasks associated with developing and producing a system, is to eliminate unnecessary delays in accomplishing the job at hand. Time is a resource in systems management, to be treated with

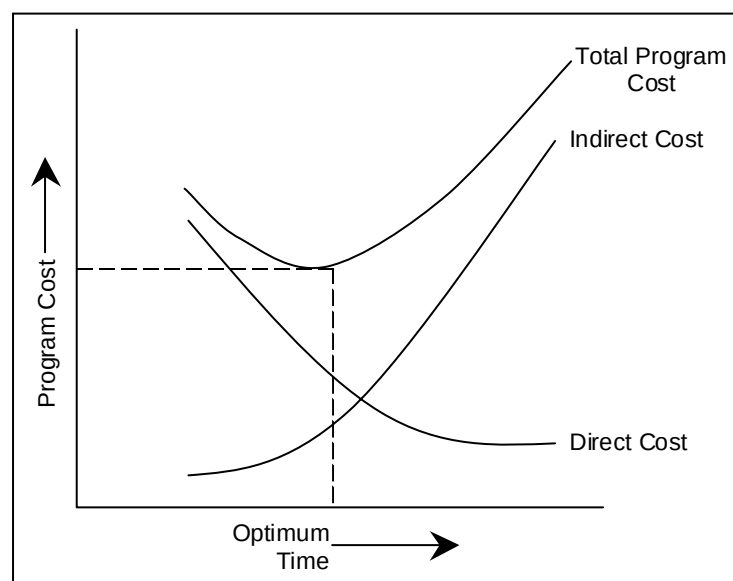


Figure 8-1. Total Cost Analysis for Selecting "Optimum" Program Duration

indifference or used well like any other resource. For projects not yet in full swing, it is important to recognize that time has economic value, and that we may be taking time too much for granted.”¹

(1) Funding could create a problem. In hungry years, the schedule is often stretched because of reduced funding.

(2) A better product could be developed if it were more thoroughly debugged and tested. However, a system does not really get wrung-out until it is in the user’s hands, regardless of advance debugging.

(3) Cost of concurrency (overlap of development and production) might lead to a decision not to overlap program phases. Such a decision might be popular in many cases, but it could never be tolerated when the pendulum swings toward the importance of time; that is, when top management says, “Get the system out the door, never mind what it costs.”²

Stretched-out schedules incur cost penalties because of inflation, additional engineering changes, and changes in key program management office positions. Another near-term cost is due to the increased chance that a program will be canceled because of obsolescence or competing technology. Stretch-outs invite cancellation. Also, long schedules with no opportunities for incorporation of improvements are a negative factor when considering a new start.

Delayed decisions increase costs. According to R. W. Peterson, former DuPont executive, “All businessmen are concerned, and properly so, about the long time it takes to move a new development from its inception to a profit status. But frequently

forgotten is the fact that a month’s delay in the early stages of development is exactly as long as a month’s delay in the later stages. While it may seem innocuous to put off a decision for a month or two in the early years of a project (or program) with an uncertain future, that delay may turn out to be just as costly as is procrastination when the final decisions are made. In short, a sense of urgency is essential to decision making in all stages of a new venture, not just the later stages.”³

The useful life of a defense system must be taken into consideration. Concentration on the system or product often overlooks a key point: whether the buyer obtains value upon delivery. The most costly product is one that appears when it no longer fulfills a useful purpose, even though it has been produced at minimum cost. Each month added to the development and production of a new high-technology system or product tends to reduce by 1 month the operational life of the system or product.

In spite of the 10-20 percent cost premium that may be paid for tight scheduling (as compared to orderly but stretched-out scheduling), the resulting longer operational life may provide greater economic value. This is looking at time only from the viewpoint of economics, i.e., acquisition cost per year of operational availability survival insurance.

Consideration of alternative plans and schedules will also help; e.g., if event so-and-so occurs, proceed with plan A; if event such-and-such occurs, proceed with plan B and so on. Anticipation and preparation for most-likely events, along with the tools described, and coupled with effective communication of the plans, can change the management style from crisis management to skillful management.

8.2 TIME MANAGEMENT AND THE PROGRAM MANAGER⁴

PMs are busy people. They have the responsibility for the management of a myriad of activities and the resources that make up the program. In addition, they are often required to perform specific program activities, especially in smaller programs. Thus, it is important that they manage their time well. Some managers could be more productive, perhaps as much as 20-40 percent, by better managing their time. A major difficulty in accomplishing this is the failure to realize that there is a time management problem and that solutions are possible. This section discusses various aspects of time management and identifies ways to better accomplish it.

In the early 1980s, a time management survey was conducted to identify the problems in achieving effective time management. More than 300 project managers in 24 industries, including the government, participated in the survey, which investigated 15 different areas. The survey identified several time management problem areas. Among the most common were time robbers and meetings.

Time robbers are simply those things that can occur on a day-to-day basis that can take away from the PMs ability and time to accomplish his/her work. There are literally dozens, if not hundreds, of such things, such as incomplete work, delayed decisions, poor communications channels, casual visitors, lack of effective program management tools, etc. Appendix B contains a list of common time robbers. The survey found that delayed decisions and poor communications were the most commonly cited time robbers. Another common problem that affects a PMs time is the

inability or reluctance to say no. If a subordinate brings a problem to the PM, the Manager must be alert to make sure not to assume responsibility for the problem, unless, of course, the situation warrants such action. If subordinates believe that PMs will assume responsibility for their problems, needless demands on the PM's time will increase.

Meetings are a fact of life in program management. However, unless they are effectively planned and conducted, they can be a severe drain on time and resources. A number of common pitfalls, if not avoided, can turn meetings into a complete waste of time. Among them are: not having a clear and focused agenda; spending too much time on trivial matters; having too many or too few meetings; not having the right people at the meetings; and not keeping an accurate record of decisions and actions assigned.

To get the most value out of meetings, the following actions should be considered:

- (1) Understand the purpose of the meeting and what results are expected
- (2) Minimize the number of people attending the meeting
- (3) Hold the meeting in a setting appropriate for the meeting objectives
- (4) Develop and distribute the agenda
- (5) Start and finish on time
- (6) Summarize meeting results and prepare and distribute minutes.

In addition to focusing on time robbers and the conduct of meetings, PMs should

also concentrate on other effective time management techniques, such as:

- (7) Prioritize activities
- (8) Devote solid time blocks for important activities
- (9) Maintain “to do” lists and time logs
- (10) Delegate
- (11) Manage by exception
- (12) Practice calculated neglect
- (13) Control access—limit casual visits and telephone calls.

8.3 SUMMARY

Planning and scheduling can do much to prevent running out of time and having to

make the least desirable decision because of lack of time. Establishing a time reserve and a “now” schedule, and recognizing the value of time in decision making all contribute to the PMs repertoire of good tools.

Sir Jeffrey Quill, manager of the British Spitfire Development Program, commented during a visit to DSMC that; “After 1935, costs weren’t particularly important. What mattered was time. We worked three shifts a day. Everything was time. Quantity and time. It turned out that we probably produced at the lowest cost, too; but the emphasis was on time.”

PMs must manage their time effectively if they are to be successful. They must be alert to those time robbers that affect their ability to accomplish their work and understand the value of proven time management techniques.

ENDNOTES

- ¹ John H. Richardson, *Time Defeats Technology*, Hughes Aircraft Company, Culver City, Calif., date unknown.
- ² *Ibid.*
- ³ Russell W. Peterson, former DuPont executive, Governor of Delaware and White House advisor, "New Venture Management in a Large Company," *Harvard Business Review*, May-June 1967, p. 72.
- ⁴ Harold Kerzner, *Project Management*, Van Nostrand Reinhold, New York, 1998, Chapter 6.

9

AUTOMATED SCHEDULING TOOLS

Previous chapters have shown that managers use schedules in a variety of ways for a wide range of purposes. Schedules are an integral part of the program planning and decision processes. Managers use them to track progress, predict future work, manage resources, analyze alternatives, identify risk, and report program status. In most cases, it is the PMs responsibility to construct, revise, maintain, and report schedule information.

The PM must do these things in a complex environment that cuts across contractor and government boundaries and includes a wide geographical area. The challenge is complicated even further by the need for instant information that must be available to a wide audience that usually requires the information in a specific format to suit unique needs.

It would be impossible to meet these challenges without automated tools. The remainder of this chapter discusses characteristics and features of some tools available on the market today and suggests criteria that anyone searching for a tool should consider. The intent is to provide an overview of the types of products that are available and the range of functions these products support. The level of detail presented is keyed to what would be useful to know about the program management software tools that would likely be used in a mid-to-large Program Office.

9.1 AUTOMATED PLANNING AIDS

The idea to use the power of the computer to assist in the planning and tracking process is not new. Industry has used automated scheduling software for at least the past 30 years. Early versions of these tools, however, usually employed a mainframe computer that batch processed data off-line and spewed reams of information for managers to analyze when they arrived at work on a Monday morning. Despite the automated tools, the process of creating, maintaining, and reporting schedule information was a daunting task.

The advent of PCs/workstations and network technologies has made life easier for managers. The market encourages software vendors to develop a wide range of programs readily available to PMs to aid them in effectively and efficiently dealing with the details involved in creating a program plan, then tracking progress.

The introductory paragraph of this chapter lists many uses of a "schedule." Software developers have responded to the managers' needs by creating programs that build schedules and support program management functions. Even the simplest program includes some program management features. The focus of the following discussion, therefore, is on the broad category of Program (often called Project) Management Software.

The focus is on providing a brief description of the *functionality* of these products, highlighting some of the desirable *features* that are available to support program management, and identifying *sources* that may be useful in determining what products are available and how their features and performance might be assessed.

9.2 FUNCTIONAL CHARACTERISTICS AND FEATURES

Most of the Program Management Software that is available today is based on a relational database design and is therefore able to support a broad range of program management activities including:

- (1) Scheduling/Tracking
- (2) Resource Planning/Management
- (3) Risk Management
- (4) Cost/Performance/Analysis
- (5) Reports and Graphics.

The extent to which the different programs support these activities varies from product to product. For example, some products provide the capability to create only Gantt charts whereas others provide the tools to make Gantt and network charts.

Program features, the way in which activities are implemented, are an important factor in considering the usefulness of a program. A convenient way to profile the functional characteristics and associated features of automated program management tools is to do so from these three perspectives:

- (1) System-Level Characteristics
- (2) Project Management/Scheduling Characteristics
- (3) Ease of Use.

System-level features have a general applicability, independent of any of the specific project-management activities supported, that add to the overall capability and desirability of the product. These features include, but may not be limited to:

- **Collaboration/Workgroup**—Enables managers/team members to use a common system of communication and allow access to common databases for the purpose of assigning tasks, updating project data, assigning resources, and reporting status.
- **Integral e-mail**—Allows exchange of messages and file attachments to other project team members from within the project management application.
- **Multiple Project/Multiple Tasks**—Supports multiple programs and tasks within a project.
- **Security**—Limits access to certain data by individual or class of user, as well as password protection for the system.
- **Open Data Base Connectivity (ODBC)**—Enables users to import data from other data sources and in various formats into their scheduling applications (e.g., data from your contractor's project database). This is a Microsoft-developed standard for exchanging data with a variety of databases.

Most programs include features that focus on program management and schedule functions. Some features offered are:

- **Project Scheduling/Tracking**—*Data Entry Templates* facilitate the entry of the initial task, time, and resource data. *On-Screen Tracking* facilitates comparison of actual performance versus the planned and allows tracking of progress by cost, time, or achievement.

- **Resource Planning/Management**—*Resource Leveling* is a capability that resolves resource conflicts by delaying tasks and assignments as well as by task splitting, which entails dividing tasks into segments with time gaps as necessary. *Resource Calendars* provide insight into the availability of a particular resource by showing working and non-working times. *Free/Total Slack Time* is a feature that is useful for adjusting under-or-over allocated resources.

- **Cost/Performance Analysis**—*Earned Value Tools* are essential for comparing actual performance with expected performance. *Cost Analysis Tool Kits* are tools for analyzing data and making forecasts. This feature may be integral to the product or available by virtue of “exporting” data to another application with this capability.

- **Reports and Graphics**—*Pre-Defined Reports* facilitate the presentation of project data. *Customization Controls* provide users with a convenient way to format reports to their own specifications. *Filters* enable the user to screen information, e.g., tasks or resources, before capturing a screen-view or preparing a report. *Embedded Graphics and Text* capability allows a user to import data from other applications for inclusion in a project report.

- **Import/Export**—*Import/Export* data from/to an external source, such as another database or spread sheets, facilitates the ability to create custom reports or conduct analyses.

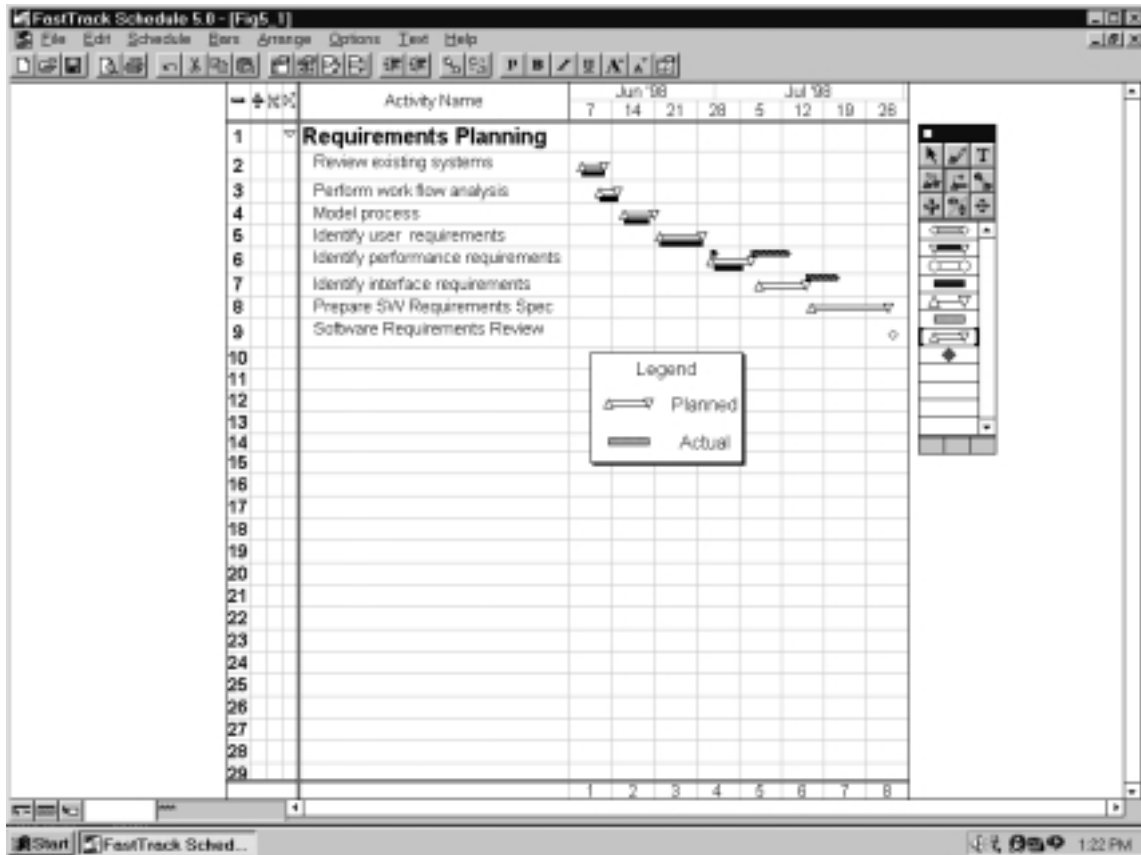
Finally, ease of use or user friendliness, is the set of qualities that represent the degree in which people can employ the software without an inordinate amount of training or regular reference to user’s manuals. User friendliness is an important consideration because program management software products can be complicated. Regardless of how powerful a program may be, if it is difficult to use, managers probably will not spend the time to learn it. Consequently, PM software is likely to be effective and desirable if users can easily learn to use it.

The following features typify user-friendly systems:

- **Graphical User Interfaces (GUIs)**—These are the screens in which a user interacts with the program. The operating environments in use today have led to the development of interface screens that enable the user to interact with the software in an intuitive way, using a variety of buttons, menu lists, and wizards.

- **On-Screen Data Entry**—The capability to create schedule information by using tools to create an on-screen graph. See Figure 9-1 for an example.

- **Help Function**—On-screen documentation as well as “context-sensitive” help in which the software displays the applicable text based on the functions being performed. This is a particularly useful feature for someone learning to use it.



**Figure 9-1. On -Screen Data Entry Using Gantt Chart Feature
(AEC Software Fast Track Schedule)**

- **Tutorials**—Program instruction on performing certain functions and guidance through a “canned” demonstration.

- **Wizards**—Templates that guide the user through various project setup, data entry, and report formatting procedures. The features discussed above are a sample of the characteristics of various program management products. Moreover, there is no common “feature list” or set of definitions that defines the various characteristics. Nonetheless, the summary should give a sense of what is available and provide the basis for a more exhaustive review as needed.

9.3 EVALUATING PROJECT MANAGEMENT SOFTWARE PRODUCTS

Choosing a software program from the wide range of available products can be complex and time consuming. The selection process should begin with an analysis of what managers want to do with the software to identify the functions that are needed. Other factors that should be part of the assessment process are consideration of personnel skill levels/training requirements, integration with enterprise (organizational) systems, hardware/system requirements, and cost.

Table 9-1. Project Management Software Functions and Criteria

USER FRIENDLINESS	
Feature	Consideration
Graphical User Interfaces (GUIs)	Logical, intuitive, all inclusive, windows compliant
Robust Help Function	Complete, easy to access, context based, examples
Wizards	Exist for major functional areas, intuitive, tailorable results
Tools	Exist for major functional areas, intuitive
Tutorials	Complete and examples
On-Screen Data Entry	Simple, logical, complete, intuitive
SYSTEM LEVEL FEATURES	
Collaboration/Workgroup Support	Desired capabilities available, non-proprietary
Integral e-mail	Exists, simple, compatibility with existing e-mail
Multi-Project & Task Support	Roll-up to higher levels, supported by reporting features
Security	Meets specific security needs, compatible w/ existing system
Open Data Base Connectivity	Data transfer with other program management S/W
PROJECT MANAGEMENT/SCHEDULING FUNCTIONS	
<i>Project Scheduling/Tracking</i>	
Multiple Schedule Methods	Create Gantt, network charts, and go from one to the other
Roll-Up	Display and report different levels
Ability to Tailor to Specific Needs	Add/delete/modify activity and event information
Relationships	Display and report dependencies among events/activities
Progress Tracking	Compare and display plans and actual progress
Critical Path Display	Highlight critical path
Interoperability w/ Other Programs	Import and export data from other programs
Total Free/Slack Time	Compute and display free and slack time
Time Estimates	Use probability distributions to compute time to complete
Time Roll-Up	Use statistical methods to compute roll-up times
<i>Resource Planning/Management</i>	
Resource Determination	Assist in determining resources needed
Resource Assignment	Allow assignment and notification of assignment to activities
Interoperability w/ Other Programs	Import and export resource data
Resource Leveling	Easy to access, permits "what if" excursions
Resource Calendars	Display resources over time
Task Assignment	Filter and display assignment of responsibility
<i>Analysis</i>	
Schedule Analysis	Allow analysis and comparison of alternative schedules
Earned Value Analysis	Assist in complete and accurate EV analysis
Cost Analysis	Includes tool kits for analysis of program cost
Resource Analysis	Compute resource utilization, identify conflicts
<i>Reports</i>	
Pre-Defined Report Formats	Automatically create reports based on program data
Customization Controls	Allow reports to be tailored for specific purposes
Embedded Graphics and Text	Add text and graphics to reports

Analyses of requirements and software evaluation are beyond the scope of this discussion. However, Table 9-1 shows some of the functions that are available in available program management software and lists some ideas for consideration when searching for the right software.

9.4 FINDING OUT MORE

The best method of gaining information about a potential project management tool is to talk to someone who is using the product. A PM in the next office may have a perfectly acceptable and proven product that he/she is using. The company under contract may have a product that it uses. If the government and contractor program

offices are going to share information, it is prudent to use the same software, if possible. At the very least, compatibility and interoperability must be demonstrated before making a decision to buy a particular product.

There is a considerable information on project management and scheduling software from a variety of sources. The *Defense Acquisition Deskbook* (DAD) has a list of tools that are being used by program offices. From a commercial aspect, specific product information is available on most companies' World Wide Web home pages. Virtually all developers provide information about their products on a web site and show links/contact to additional sources.

APPENDIX A

INTEGRATED MASTER SCHEDULE DESCRIPTION

The Integrated Master Schedule (IMS) for a program should be a time reference baseline for the activities and events that make up the program. It should be incorporated into the program plan and linked to approved performance and cost objectives. The IMS is developed by the contractor from the Integrated Master Plan (IMP), which documents all the tasks required to deliver a high quality product and to facilitate success throughout the product's life cycle. In an Integrated Product and Process Development (IPPD) environment, which is the standard approach for all DoD programs, the IMP and IMS provide an overarching framework against which the Integrated Product Teams (IPTs) can function, helping them understand their work within the context of the total program.

The IMP and IMS evolve as the program matures. During the initial stages of Concept Exploration, the integrated plan is preliminary and its purpose is to provide an understanding of the scope of work required and the likely structure of the program. It is constructed to depict a likely progression of work through the remaining phases, with the most emphasis on the current and/or upcoming phase (especially the period to be contracted for next). As the program is defined, the IMP is iterated several times, each time increasing the level of detail and confidence at which all essential work has been identified. The specific format for this plan is not critical; however, it usually reflects an Event/Accomplishment/Criteria hierarchical structure—a

format that greatly facilitates the tracking and execution of the program.

In some cases, a preliminary IMP and its corresponding IMS may be developed by the government but include industry inputs obtained through open communications with potential sources during the pre-solicitation phase of the acquisition. Contractors are normally required to submit formal IMP and IMS with their proposals and to develop more detailed IMP/IMS versions after the contract is awarded.

The IMS is event driven and is developed with participation of all program stakeholders. It should identify all tasks that need to be accomplished, their logical order, and the input conditions necessary to complete each task. When documented in a formal plan and schedule, this event-driven approach can help ensure that all tasks are integrated properly and that the management process is based on significant events in the acquisition life cycle and not on arbitrary calendar events. Developing the program schedule presents an opportunity to identify critical risk areas. As IPT members estimate the times to complete specific tasks, events that may cause delays will become apparent. These events are potential areas of risk that the IPT should consider for further analysis.

The IMS begins as an IMP with dates—the starting points are the events, accomplishments, and criteria that make up the plan. At a minimum, an IMS shows the expected

start and stop dates for each activity in the plan, but each activity may be broken down into lower-level tasks that will be used to manage the program on a day-to-day basis. The schedule can be expanded downward to the level of detail appropriate for the scope and risk of the program. Programs with high risk show much lower levels of detail in the integrated master schedule in order to give the visibility necessary to manage risk. The more detailed the IMS, however, the greater the cost to track and update the schedule. Under acquisition reform initiatives, the dates in the IMS usually are not made contractually binding so as to allow the flexibility to take full advantage of event-driven scheduling.

Additional information on the development of IMSs can be found in various sections of the *Defense Acquisition Deskbook* and in the *DoD Integrated Product and Process Development Handbook* dated August 1998. Commercial standards EIA 632 and IEEE 1220-1994 can also be consulted for more information on developing master plans and schedules. See <http://www.eia.org/eng/published.htm> and <http://standards.ieee.org> for information on how to obtain these standards. A DoD Data Item Descriptor (DI-MISC-81183A) has been developed for IMS guidance; it is attached to this Appendix as Tab 1.

USE OF INTEGRATED MASTER SCHEDULES

The primary purpose of the IMS is to track schedule variations. By linking the IMS to the IMP, it can also be used to track the activities that provide functional and life-cycle inputs to product development. In this role it provides a crosscheck not only that the inputs were obtained, but also that

they were obtained at the right time. In addition, the IMS can be useful for the following events/activities that are common to all programs.

PROGRAM REVIEWS

The IMS can be a framework for periodic program reviews within the program management office (PMO). If constructed properly, the schedule will illustrate the various levels of the program and will be compatible with the program cost/schedule control system reports.

Program reviews can be an excellent forum for resolution of schedule conflicts and the genesis for controlled changes to the schedule from within the PMO. Most key members of the PMO team are present at these reviews; therefore, proposed schedule changes or slips can receive wide dissemination within the organization.

WHAT IF" EXERCISES

The IMS can serve as the framework for "what if" exercises imposed on programs from outside the PMO. Schedule changes can be plotted manually by using overlays. Using the same grid coordinates on an overlay allows the PMO team to see, clearly and graphically, the effect of the compressions or extensions of sub-milestones on the program. It may be even easier (and more productive) for the PMO team to run "what if" exercises on a computerized schedule. Without a master schedule as a baseline, these exercises can take longer to accomplish and they may overlook important variances from the program's established baseline schedule or plan.

PROGRAM BRIEFINGS

The IMS can serve as a baseline for program reviews at higher headquarters and other reviews or briefings outside the PMO. Most programs have key milestones taken from the master schedule and presented in summary form on viewgraphs or slides. If these do not show the detail required to make a point, the time span shown can be reduced to the point where the details become visible.

SCHEDULE DISCIPLINE

To be effective, an IMS must be kept up-to-date and accurate. Maintenance of the IMS requires a process similar to that inherent in configuration control—one that establishes discipline through a set of rigorous procedures for managing schedule change. The degree of schedule discipline imposed within the PMO can be a major factor in the success of a program. The underlying philosophy of the schedule control process should reflect centralized control of the IMS. That is, changes to the IMS baseline should be made only with the approval of the P2M or his/her designated representative and with full

justification and an understanding of the impact of the changes on the overall program. Following are examples of some simple procedures that, if practiced, will instill discipline and prevent the unauthorized release of schedule information that has not been approved for inclusion in the IMS.

- Program changes, whatever the source, should start as proposals and, if approved, grow into a firm plan. Eventually, they are incorporated into the IMS as changes. The question of when to plot these changes is a matter of judgment and should reflect the PM's policy. Each change should be plotted as a proposed or tentative change until approved.
- A permanent record of each change should be maintained. If the program schedule slips, it should be documented until documentation no longer serves a useful purpose.
- Whenever copies of the IMS are made, they should be dated and authenticated by the signature of the PM or the appointed schedule manager. Undated and unauthenticated schedules should not be released outside the PMO.

DATA ITEM DESCRIPTION		Form Approved OMB NO. 0704-0188	
Public reporting burden for this collection of information is estimated to average 110 hours per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204 Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503			
1. TITLE Integrated Master Schedule (IMS)		2. IDENTIFICATION NUMBER DI-MISC-81183A	
3. DESCRIPTION/PURPOSE The IMS is an integrated schedule developed by logically networking detailed program activities. The contract Integrated Master Plan (IMP) is the foundation of the program schedule and provides a hierarchy for schedule traceability and summarization. IMP events, accomplishments, and criteria are included in the schedule to monitor progress. This information will be used to verify attainability of program objectives, evaluate the progress of the government and contractor team toward meeting the program objectives, and to integrate program schedule among all related components.			
4. APPROVAL DATE (YYMMDD) 960209	5. OFFICE OF PRIMARY RESPONSIBILITY (OPR) F/ASC/FMCS	6a. DTIC APPLICABLE	6b. GIDEP APPLICABLE
7. APPLICATION/INTERRELATIONSHIP 7.1 This Data Item Description (DID) contains the format and content preparation instructions for the data product generated by the specific and discrete task requirement as delineated in the contract. 7.2 This DID may be applied to programs which utilize the Work Breakdown Structure (WBS) during the concept exploration, demonstration and validation, engineering and manufacturing and development, and production phases. 7.3 This DID supersedes DI-MISC-81183.			
8. APPROVAL LIMITATION		9a. APPLICABLE FORMS	9b. AMSC NUMBER F7180
10. PREPARATION INSTRUCTIONS 10.1 Format . This precedence logic diagram shall be in the contractor's format in the form of a network, milestone, and Gantt chart. This diagram shall be provided in digital format. 10.2 Content . The schedule shall contain all of the contract IMP events and milestones, accomplishments, criteria, and activities from contract award to the completion of the contract. The schedule shall be an integrated, logical network-based schedule that correlates to the program WBS, and is vertically and horizontally traceable to the cost/schedule reporting instrument used to address variances (such as Cost Performance Report (CPR), Cost/Schedule Status Report (C/SSR), etc.) It shall have a numbering system that provides traceability through the IMP and Statement of Work (SOW). It shall contain program events and milestones and definitions, summary, intermediate and detailed schedules, and periodic analysis of progress to date. It shall be possible to access the information by product, process, or organizational lines. Descriptions of the key elements are as follows: 10.2.1 Program milestones and definitions. Key programmatic events defined by IMP, the contracting agency or weapon system contractor which define progress and completion in each WBS element along with the definition for successful completion of the milestone. 10.2.2 Summary master schedules. A graphical display of top-level program activities and key events and milestones of the IMP which depict major work activities in an integrated fashion at the summary level of the WBS, e.g. level 1-3 of the WBS. 10.2.3 Intermediate schedules. A graphical display of top-level program activities and key milestones which includes all associated accomplishments of the IMP, traceable to the WBS element as necessary to display the work effort at the intermediate level of summarization, e.g. level 3-5 of the WBS as appropriately tailored. 10.2.4 Detailed schedules. A graphical display of detailed activities and milestones which depict work activities in a particular work breakdown structure element, to include the criteria associated with each accomplishment of the WBS element as well as any additional activities necessary to display the work effort to detailed WBS levels, e.g. level 4-8 of the WBS as appropriately tailored.			
11. DISTRIBUTION STATEMENT Distribution Statement A: Approved for public release; distribution is unlimited.			

Block 10, Preparation Instructions (Continued)

10.2.5 Periodic analysis. A brief summary which identifies progress to date, variances to the planned schedule, causes for the variance, potential impacts and recommended corrective action to avoid schedule delays. For each program milestone planned, forecasted and actual completion dates shall be reported. The analysis shall also identify potential problems and a continuing assessment of the network critical path. Thresholds for impact reporting shall be identified on the DD Form 1423, CDRL.

10.2.6 Integrated program network. Logical diagram of all activities in the program. The key elements of the integrated network to be constructed in the diagram are as follows:

- a. Milestone or event - A specific definable accomplishment in the program/project network, recognizable at a particular point in time. Milestones are numbered and may be contained within an activity box.
- b. Activity or task - A time consuming element, e.g. work in progress between interdependent events, represented by an activity box.
- c. Duration - Planned length of time needed to accomplish an event/activity.
- d. Relationships - A line that defines how two activities or events are logically linked. It can take up to four (4) forms:
 - (1) FS (finish to start) - An activity must finish before another can start.
 - (2) SS (start to start) - An activity depends on the start of another activity.
 - (3) FF (finish to finish) - One activity cannot finish until another activity is finished.
 - (4) SF (start to finish) - An activity cannot finish until another activity starts.
- e. Slack or Float - Extra time available on an activity before it will impact an activity on the critical path.
- f. Lag - The delay or wait period between two tasks.
- g. Critical Path - A sequence of activities in the network that has the longest total duration through the program or project. Activities along the critical path have zero or negative slack/float. It should be easily distinguished on the report formats, e.g. a thick line, patterned or in red ink. This should be calculated by computer-based software.
- h. Target Start (TS) - A program defined date of when an activity should start. This is an operator-defined date rather than a computer-calculated date.
- i. Target Complete (TC) - A program defined date of when an activity should finish. This is an operator-defined date rather than a computer-calculated date.
- j. Actual Start (AS) - Actual start date of an activity.
- k. Actual Finish (AF) - Actual finish date of an activity.
- l. Early Start (ES) - The earliest start date an activity can begin the precedence relationships. Computer-calculated date.
- m. Early Finish (EF) - The earliest finish date an activity can end. Computer-calculated date.
- n. Late Start (LS) - The latest start date an activity can start without delaying the program or project target completion date. Computer-calculated date.

Block 10, Preparation Instructions (Continued)

o. Late Finish (LF) - The latest finish date an activity can have without affecting the program or project target completion date. Computer-calculated date.

p. Percent Complete (PC) - Actual progress of an activity from its start to its finish.

10.3 Master Integrated Program Schedule. It shall display all of the proposed activities, events, and milestones from contract award to the completion of the contract.

10.4 Descriptive titles. Activities, tasks, events, and milestones shall be labeled with a brief descriptive title, numbered or coded and contain time constraints (e.g. duration, TS, ES, EF, LS, LF, etc.). Standard abbreviations may be used to conserve space. Descriptive titles used on activities, events, and milestones shall be identical on all program schedules. A legend shall be provided to aid in ease of reading the schedules.

10.5 Schedule risk. The schedule shall include a description of the approach that will be taken to limit the schedule risks identified as a result of the contractor's risk assessment. Risk shall be defined considering impact on cost and technical performance and assessing the probability of schedule change. Additionally, technical performance measurement tasks and their correlation with contractual cost/schedule elements permit assessment of the program effort in terms of the schedule as well as cost of work increments. As technical performance measurement tasks, as well as cost reviews, reveal potential impacts to the schedule these risks will be identified.

10.5.1 Schedule Risk Assessment (SRA). Optimistic, pessimistic, and most likely durations for each MIPS activity/task and milestone/event shall be provided as the basis for determining the probability of meeting schedule dates. The government will assess the durations and use an appropriate cumulative probability (0-100%) for the chosen milestones to determine expected completion dates.

APPENDIX B

Common Time Robbers¹

- Incomplete work
- A job poorly done that must be done over
- Poor communications channels
- Uncontrolled telephone calls
- Lack of adequate responsibility and commensurate authority
- Poor functional performance and status reporting
- Changes without direct notification/explanation
- Casual visitors and conversations
- Waiting for people
- Failure to delegate, or unwise delegation
- Poor retrieval systems
- Lack of information in a ready-to-use format
- Day-to-day administration
- Spending more time than anticipated in answering questions
- Late appointments
- Impromptu tasks
- Having to explain “thinking” to superiors
- Too many levels of review
- Too many people in a small area
- Misplaced information
- Record keeping
- Shifting priorities
- Indecision or delaying decisions
- Procrastination
- Setting up appointments
- Too many meetings
- Monitoring delegated work
- Unclear roles/job descriptions
- Unnecessary crisis intervention
- Need to get involved in details to get job done
- Not enough proven or trustworthy managers
- Vague goals and objectives
- Too many people involved in minor decision making
- Lack of technical knowledge
- Lack of authorization to make judgment decisions
- Unreasonable time constraints
- Lack of commitment from higher authorities
- Too much travel
- Lack of adequate project management tools

- Poor functional communications/ writing skills
- Inability to relate to peers in a personal way
- Rush into decisions/beat the deadline
- Lack of reward (“a pat on the back can do wonders”)
- Expecting too much from one’s staff and oneself
- Going from crisis to crisis
- Conflicting directives
- Fire drills
- Lack of privacy
- Lack of challenge in job duties
- Bureaucratic roadblocks (“ego”)
- Empire-building line managers
- Too much work for one person to handle effectively
- Excessive paperwork
- Lack of clerical/administrative support
- Workload growing faster than capacity
- Dealing with unreliable subcontractors
- Personnel not willing to take risks
- Demand for short-term results
- Lack of long-range planning
- Being overdirected
- Overreacting management
- Poor lead time on projects
- Documentation (reports/red tape)
- Large number of projects
- Inadequate or inappropriate requirements
- Desire for perfection
- Lack of dedication by technical experts
- Lack of project organization
- Constant pressure
- Constant interruptions
- Project budget problems
- Shifting of functional personnel
- Lack of qualified manpower

ENDNOTES

¹ Harold Kerzner, *Project Management*, Van Norstand Reinhold, New York, NY, 1998, Chapter 6.

APPENDIX C

GLOSSARY

ACQUISITION STRATEGY — A business and technical management approach designed to achieve program objectives within the resource constraints imposed. It is the framework for planning, directing, contracting for, and managing a program. It provides a master schedule for research, development, test, production, fielding, modification, postproduction management, and other activities essential for program success. Acquisition strategy is the basis for formulating functional plans and strategies [e.g., test and evaluation master plan (TEMP), acquisition plan (AP), competition, prototyping, etc.].

ACTIVITY — A task or measurable amount of work to complete a job or part of a project.

ACTUAL COST OF WORK PERFORMED (ACWP) — The costs actually incurred and recorded in accomplishing the work performed within a given time period.

ARROW DIAGRAM METHOD (ADM) — A type of network diagram that labels the activities on the lines connecting nodes.

BAR CHART — The detailed graphical working plan of a part providing sequence and time for the job scheduled ahead and progress to date.

BUDGETED COST OF WORK SCHEDULED (BCWS) — The sum of the budgets for all work (work packages, planning pack-

ages, etc.) scheduled to be accomplished (including in-process work packages), plus the amount of level of effort and apportioned effort scheduled to be accomplished within a given time period. (Planned Value)

BUDGETED COST OF WORK PERFORMED (BCWP) — A measurement of work performed in cost/schedule control systems criteria (C/SCSC) terminology. BCWP is a measurement of work performed as compared to the original plan. (Earned Value)

BUDGETING — The process of translating resource requirements into a funding profile.

CRITICAL PATH METHOD (CPM) — A technique that aids understanding of the dependency of events in a project and the time required to complete them. Delayed activities that have an impact on the total project schedule are critical and said to be on the critical path.

EARNED VALUE MANAGEMENT SYSTEM (EVMS) — An integrated management system that coordinates work scope, schedule, and cost goods and objectively measures progress toward these goals. It is based on an industry-developed set of 32 guidelines adopted for use by DoD in 1999 for evaluation of contractor management systems. A complete listing of the guidelines is contained in DoD 5000.2-R, Appendix VI.

FLOAT — The period of time that an activity may be delayed without becoming a critical activity. Also known as slack or path float/slack.

FREE FLOAT — The float that a single activity can experience without affecting any other activity.

GANTT CHART — A graphic portrayal of a project which shows the activities to be completed and the time to complete represented by horizontal lines drawn in proportion to the duration of the activity. Some Gantt charts will be able to show the float for the activity.

INTEGRATED MASTER PLAN (IMP) — An event-based plan that depicts the overall structure of the program and the key processes, activities, and milestones. It defines the accomplishments and criteria for each event in the plan.

INTEGRATED MASTER SCHEDULE (IMS) — The detailed task and timing of the work effort in the IMP. A networked schedule that identifies all IMP events, accomplishment, and criteria, and the expected dates of each.

INTEGRATED PRODUCT AND PROCESS DEVELOPMENT (IPPD) — A management technique that simultaneously integrates all essential acquisition activities through the use of multidisciplinary teams to optimize the design, manufacturing, and supportability processes. IPPD facilitates meeting cost and performance objectives from product concept through teamwork through Integrated Product Teams (IPTs).

INTEGRATED PRODUCT TEAM (IPT) — Team composed of representatives from all appropriate functional disciplines working together to build successful programs, identify and resolve issues, and make sound and timely recommendations to facilitate decision making. There are three types of IPTs: overarching IPTs (OIPTs) focus on strategic guidance, program assessment, and issue resolution; working IPTs (WIPTs) identify and resolve program issues, determine program status, and seek opportunities for acquisition reform; and program-level IPTs focus on program execution and may include representatives from both government and after contract award industry.

LINE OF BALANCE (LOB) — A graphic display of scheduled units versus actual units produced over a given set of critical schedule control points on a particular day.

MASTER PROGRAM SCHEDULE (MPS) — The top-level schedule for the program. It is prepared by the government and includes all policy and contractual events/activities. It is derived from the Program WBS and provides the baseline for all subordinate schedules. It sometimes is called the program structure/schedule.

MILESTONE (MS) — The point when a recommendation is made and approval sought regarding starting or continuing (proceeding to next phase) an acquisition program. Milestones are: 0 [Approval to Conduct Concept Studies], I [Approval to Begin a New Acquisition Program], II [Approval to Enter Engineering & Manufacturing Development (EMD)], and III [Production or Fielding/Development and Operational Support (PF/DOS) approval]. A significant event that marks certain

progress, such as completion of a phase of the project.

MILESTONE CHART — A graphic portrayal of a program/project that shows the events to be completed on a timeline.

NETWORK SCHEDULE — A scheduling technique that provides the means for defining task relationships and relationship lags. These may include such precedence relationships as "Start to Start," "Finish to Finish," and "Start to Finish."

PERT — See Program Evaluation Review Technique.

PERT Chart — A graphic portrayal of milestones, activities, and their dependency upon other activities for completion and depiction of the critical path.

PRECEDENCE DIAGRAM METHOD — A network diagram in which the activities are labeled in the nodes, usually boxes.

PRODUCTION SCHEDULES — Chronological controls used by management to regulate efficiently and economically the operational sequences of production.

PROGRAM EVALUATION REVIEW TECHNIQUE (PERT) — A technique for management of a program from inception through to completion by constructing a network model of integrated activities and events and periodically evaluating the time/cost implications of progress.

RESOURCE LEVELING — A process whereby resources are sorted out among tasks and activities to identify and avoid conflicts between scheduling and availability.

RISK — A measure of the inability to achieve program objectives within defined cost and schedule constraints. Risk is associated with all aspects of the program, e.g., threat, technology, design processes, work breakdown structure (WBS) elements, etc. It has two components: the probability of failing to achieve a particular outcome and the consequences of failing to achieve that outcome.

RISK MANAGEMENT — All plans and actions taken to identify, assess, mitigate, and continuously track, control, and document program risks.

SCHEDULE — Series of things to be done in sequence of events within given period; a timetable.

SCHEDULE RISK — The risk that a program will not meet its acquisition strategy schedule objectives or major milestones established by the acquisition authority.

SCHEDULE VARIANCE — A metric for the schedule performance of a program. It is the algebraic difference between earned value (BCWP) and planned value (BCWS) (Variance = BCWP - BCWS). A positive value is a favorable condition while a negative value is unfavorable.

SCHEDULING — The prescribing of when and where each operation necessary to the manufacture of a product is to be performed.

WORK BREAKDOWN STRUCTURE (WBS) — An organized method to break down a project into logical subdivisions or subprojects at lower and lower levels of details. It is very useful in organizing a project. See MIL-HDBK 881 for examples of WBSs.

APPENDIX D

BIBLIOGRAPHY

Q. W. Fleming, J. W. Bronn, and G. C. Humphreys, *Project and Production Scheduling*, Probus Publishing Co., Chicago, IL, 1987.

H. Kerzner, *Project Management: A Systems Approach to Planning, Scheduling, and Controlling*, Van Nostrand Reinhold, New York, NY, 1998.

M. D. Rosenau, Jr., *Successful Project Management: A Step-by-Step Approach With Practical Examples* (2nd Edition), Van Nostrand Reinhold, New York, NY, 1992.

D. C. Cleland, *Field Guide to Project Management*, Van Nostrand Reinhold, New York, NY, 1998.

J. J. Mayer, *Time Management for Dummies* (2nd edition), IDG Books Worldwide, Inc., Foster City, CA, 1999.

Defense Systems Management College, *Acquisition Strategy Guide*, DSMC, Fort Belvoir, VA, 1998.

Defense Systems Management College, *Earned Value Management Textbook*, DSMC, Fort Belvoir, VA, April 16, 1998.

Office of the Under Secretary of Defense (Acquisition and Technology), *DoD Integrated Product and Process Development Handbook*, DoD, Washington, DC, 1998.

D. T. Hulett, "Project Schedule Risk Assessment," *Project Management Journal*, March 1995.

PMI Standards Committee, *A Guide to the Project Management Body of Knowledge*, Project Management Institute, Newton Square, PA, 1996.

J. R. Knutson, *How To Be A Successful Project Manager*, IEEE Successful Management Series, Undated.

J.P. Lewis, *Project Planning, Scheduling & Control*, McGraw-Hill, New York, NY, 1995.

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