Techniques Handbook-Project Management

Work Breakdown Structures

ERDA Handbook 0805.3 Part 1

U.S. Energy Research & Development Administration

Division Of Management Information
& Telecommunications

DISCLAIMER

PREFACE

The ERDA Handbook on project management techniques will consist of nine parts, each dealing with a specific technique. The parts are:

- Part I : Work Breakdown Structures (WBS)
- Part II : Milestone Planning Techniques
- Part III : Network Techniques
- Part IV : Line of Balance (LOB)
- Part V : GANTT Charts
- Part VI : Cost/Schedule Performance Measurement
- Part VII : Technical Performance Measurement
- Part VIII : Configuration/Data Management
- Part IX : Design-to-Cost

Each part of the handbook provides a detailed description of the subject technique and methodology, together with information for the application and implementation of the technique at the project management level.

One purpose of the handbook is to provide the Project Manager with the essential information necessary

- for a decision to implement a given technique on his project, and
- for actual application of the technique after such decision has been made.

Part I, on Work Breakdown Structures, follows this preface.

OVERVIEW

INTENT

The Work Breakdown Structure technique is primarily a project management planning technique which is aimed at defining, within an overall conceptual framework, the detailed products and work effort to be accomplished for successful achievement of the project objective(s).

APPLICATION

The WBS technique directs the attention of the ERDA project manager, the contractor project manager, and their respective staffs, to insuring that the total project effort is fully planned and that all efforts contribute directly to the project objectives. The technique requires identification of the major end items to be produced by the project effort. By successive subdivision of each end item into increasingly detailed categories and subcategories of product and work, the WBS defines the total project effort in terms of manageable segments (packages) of work which are assignable to a single unit within the performing organization.

SCOPE

The WBS technique is used to: (1) identify the major end item(s) or end product(s) necessary to accomplish the project objectives, (2) define the detailed work packages required for production of each end item, and (3) revise, modify, or change the WBS elements as the project effort progresses. Once the WBS is established, it may be used in conjunction with other management effort and techniques to: (1) assign responsibility for each work package to a performing unit of the project organization, (2) establish plans and schedules, (3) allocate resources, (4) determine cost estimates and assessments of cost accountability, (5) assess the status of project effort, (6) evaluate work performance, and (7) determine the necessity for, and the work requirements of, reprogramming the project effort.

CONTENTS

A. BASIC INFORMATION

TERMINOLOGY

☐ Work Breakdown Structure (WBS): The Work Breakdown Structure is a product-oriented task hierarchy of all of the work to be performed in accomplishing the project objectives. The product(s) may be hardware, software, support services, tests, documentation, or other quantified elements of the project objectives. The task hierarchy has, as its first level, the categories of the major "end-items" of the project. The successive levels provide increasingly detailed definition of the individual work tasks which contribute to the production of end items. The scope of and the number of levels in the task hierarchy depend upon the scope and complexity of the individual project. Where the project involves contract effort, the portion of the WBS relating to the contract effort is developed in two segments; i.e.: (1) the project summary WBS, and (2) the contract WBS.

☐ Project Summary Work Breakdown Structure (PSWBS): A summary WBS tailored by project management to the specific project and identifying the elements unique to the project. Generally, the PSWBS will identify project elements through the third level.

☐ Contract Work Breakdown Structure (CWBS): A complete WBS for a contract, developed and used by the contractor in accordance with the contract statement of work (SOW). The CWBS is comprised of, and based upon the selected PSWBS elements included in the contract, and the extensions of these by the contractor to cover the lower levels of the WBS.

☐ Work Breakdown Structure Element: Any one of the individual items or entries in the WBS hierarchy, regardless of level.

Work Package: A segment of effort required to complete a specific job; such as a research or technological study or report, an experiment or test, a design, a specification, a piece of hardware, an element of software, a process, a construction drawing, a site survey, a construction phase element, a procurement phase element, or a service, which is within the responsibility of a single unit within the performing organization. The work package is usually an element of the lowest level of the WBS.

TECHNIQUES SUMMARY

The development of the WBS begins with the identification of the major end item(s) or end product(s) to be produced by the project effort to meet the requirements of the project objectives. The major end items so identified are the elements of the first level of the WBS. For many projects, there may be but one major end item constituting the first level of the WBS (e.g.: a research study; an engineering pilot model development; a computer system, etc.). Other projects may have several major end items as first level elements to the WBS (e.g.: projects progressing through a combination of research, development, and production phases; projects providing diverse services, products, or components to a larger project or to an overall program; etc.). If, in the judgement of the project manager, the project is of the scope and complexity to warrant it, project management and system test and evaluation are also identified as first level elements of the WBS.

When the first level WBS elements are identified, each is subdivided into those major work segments which together contribute to the make-up of the whole of the associated first level element. These work segments are identified as the second level elements of the WBS. For example, if one of the first level WBS elements is a prototype electrical power

generating plant, second level elements associated with this first level element would be the major subsystems of the plant, such as the prime power subsystem, the prime electrical generator subsystem, the auxiliary subsystem, the control and instrumentation subsystem, the distribution subsystem, etc. For the example cited, an additional second level element relating to integration, test, and evaluation would also be required.

- The second level elements are broken down to third, fourth, etc. levels of the WBS, with each successive indenture reducing the scope, complexity, and cost of identified lower level WBS element. The procedure is usually continued until an element representing a manageable work package assignable to a single operating unit of the project organization is reached. However, the levels of sub-indenture may not, and need not, be the same in applying the work breakdown procedure to each of the WBS elements at the same level. Variations in the sub-levels will occur not only from one project to another, but within a given project depending upon the scope of the project, the type of effort involved in each element at a given level, the organizational structure and requirements of the project, and the judgement and decision of the project manager.

- When completed, the WBS serves as the basis for assignment of the element and work package responsibilities to the appropriate division, department, group, or unit of the project organization. In conjunction with other management techniques, schedule, cost, and resource estimates can be obtained for each element, starting with the lowest level elements.

- Upon completion of the foregoing, procedures for periodic reporting and updating of cost/performance status and progress relating to the WBS are established for inclusion in the project data and information reporting requirements. Included in these procedures would be provisions for controlling and reporting changes, modifications, deletions and additions to the WBS.

RELATIONSHIP TO OTHER MANAGEMENT TECHNIQUES

☐ The other management techniques covered in this Handbook are all related to the WBS technique. Together with the WBS technique, they provide mutual support to the management planning function, and thus are complementary to a greater or lesser degree depending upon the scope and complexity of the project on which they may be implemented.

☐ Milestone planning focuses on the sequential achievement of significant actions necessary for successful completion of the project objectives. It provides the schedules and sequential relationships among major activities and events of the project effort. The WBS provides the identification of many of the activities and events which will go into development and application of the milestones planning technique.

☐ Network techniques (such as PERT and CPM) depict the interrelationships and interdependencies of the planned project activities and events, and evaluate the critical path (sequence) of activity completion, as affected by constraints of time and cost (and possibly, resources). The activities and events depicted in the network should be clearly related to both the WBS and the project milestones.

☐ Gantt charts, when used in conjunction with the WBS, identify individual task and job orders, depicting their scheduled and actual progress against time. They are derived almost entirely from the lowest "work package" element of the WBS. Thus, they represent the ultimate breakdown of the project work to the detailed tasks (and manpower) of a unit or individual for accomplishing the work package effort.

☐ The Cost/Schedule Performance Measurement, Technical Performance Measurement, and Design-to-Cost techniques emphasize the review and control of specific aspects of the project effort, i.e.: cost, schedule, technical performance. The size, scope, complexity, and type of project

will determine the applicability of a given one of these techniques to the project; e.g.: the Design-to-Cost technique can rarely, if ever, be employed on a research project. When implemented, these techniques, will rely upon data derived from the WBS, as well as the milestones and network techniques. For example, a contract WBS (CWBS) is fundamental to the Cost/Schedule Performance Measurement, where the project involves contractor effort.

☐ The Configuration/Data Management technique is a management control method concerned with identification, control, accounting, and auditing of the project product(s). When implemented on a project, elements of the WBS provide data needed for product identification and control.

☐ The Line of Balance (LOB) technique provides a means of controlling detailed and repetitive production processes. The application of the LOB technique is almost entirely restricted to projects involved in the production and delivery of quantities of hardware on a time-phased schedule extending over a prolonged period of time. Elements of the WBS relating to hardware production and procurement activities can provide data needed to establish the project LOB implementation plan.

MANAGEMENT CONSIDERATIONS

☐ The management of nearly all projects will benefit from the application of the WBS technique. Projects which are basically simple in nature, not of long duration, nor calling for a large expenditure of effort and resources, may not require a detailed hierarchical WBS. This will depend upon the professional judgement of the project manager. Good management practice would indicate, however, that an equivalent definition of specific work elements to be accomplished would be developed to the extent necessary to ensure production of the project end item(s).

The WBS is not an end in itself. It is a tool to be used by management to ensure the accomplishment of the project objectives with a minimum expenditure of resources and time on unfruitful effort. As such, the initial development of the WBS requires detailed effort, on the part of the project manager, supporting staff, and subordinate management personnel. This will ensure that it reflects the project management needs and objectives, and represents the level and way which responsibilities are designated and work efforts are to be organized, managed, and accounted for. As the project progresses, continuing management effort will be required for updating, reviewing, and evaluating the status and progress of the project effort as defined by the WBS. Since project management and activity is a dynamic process, changes in the WBS can be expected to become necessary as the project progresses. Such changes will require consideration and decision, during the management review and evaluation effort, also.

In the development of the WBS, care must be taken to check that the WBS provides for a logical subdivision of the project work, and that the subdivision elements defined at each successively lower level of the WBS are complete and represent all of the effort required to complete the higher level element from which they derive. The development of the WBS from the top level downward to the successive lower levels facilitates this audit effort.

In developing the sublevels of the WBS relating to hardware and software elements, consideration must be given to the synthesis of these sub-elements to produce the associated upper level element. To provide assurance that the synthesis of the sub-level elements does, in fact, provide the desired next-level element, it is usually necessary to identify and specify an additional sub-element to the WBS representing the test and evaluation of the assembled sub-elements.

- When the project involves contract effort, the project WBS should normally be identified to the third level in those areas in which contract effort is to be provided. Subsequent lower levels in these areas should be specified in the contract as a CWBS to be developed by the contractor, subject to approval by project management.

- The WBS provides an appropriate framework for management assignment of responsibility to the appropriate division, department, group, or unit of the project and/or contractor management. Interface responsibilities may also be defined and/or determined, and assigned during this management process.

- The WBS also provides a logical framework for the application of other management techniques in determining cost and schedule estimates for the project. Such estimates should be obtained for each element, starting with the lowest level elements of the WBS. The total cost estimates at a given level should equal the aggregate of the constituent elements at the next lower level. Although the aggregation of lower element schedule estimates to the next upper level will not necessarily be additive due to overlap and congruency of activities at the lower levels, they will provide inputs for use in milestone planning, and direct data for use in the network techniques (PERT/CPM), if such are used by project management.

- Reporting requirements for cost and progress review and evaluation should be established on a periodic basis. The reports can be of a summary nature providing actual cost expenditures and percent of element activity completed to date for each WBS element in progress, together with brief descriptions of anticipated problems if such exist. It should be possible to combine many of the WBS, milestones, and network (if implemented) reporting requirements in a single report format.

B. METHODOLOGY

PROJECT APPLICATION

The WBS technique is applicable to all types of projects, i.e.: Research, Research and Development, Development, Hardware/Software Systems, Production Construction, or other. The extent to which the technique is applied and the level to which it is developed will depend upon the scope, complexity, and duration of the individual project.

The elements of the WBS will differ from project to project depending upon the type or project and type of effort involved. Examples of the types of work are:

- Discrete quantities of work with a definable end product and a clearly recognizable beginning and end. Hardware, software, production, and some development projects will reflect this category of WBS element.

- Level-of-effort (LOE) work which cannot be associated with a defineable end product or result, but is measured only in terms of resources actually consumed in a time-phased budgeted rate of consumption. Typical examples of LOE are project management, administrative reports, specialized project and technical support activities, marketing, etc.

WBS DEVELOPMENT

The first effort in the development of the WBS is the identification of the major end item(s), or end product(s) to result from the project effort. This identification is normally obtained from the quantified project objectives, and examination of the project statement of work. if such exists. These end items become the first level elements of the WBS.

As an example, a research project is to conduct a concept study on new applications of exotic energy sources, and based upon the results of the study, develop a computerized mathematical model for further detailed investigation. The end items and the first level elements of the WBS are identified as

- Concept Study,
- Mathematical Model.

In addition, a third first level element is identified as

- Project Management.

After the first level elements are identified, subdivide each into the logical major work segments associated with each. These are identified as the second level WBS elements. For the research project example, the second level elements associated with the Mathematical Model first level element are identified as

- Mathematical Formulation
- Computer Program
- Test and Evaluation.

Upon completion of the second level element identification, each is again subdivided into logical work segments of reduced scope, complexity, and cost. These represent the third level WBS elements. In the research project example, the third level elements associated with the second level Computer Program element are

- Design,
- Programming,
- Test and Integration.

Continue the subdivision of each element into successive sub-levels until the lowest element represents a manageable package assignable to a single operating unit of the project organization. In most cases, the lowest level element will not be at the finely detailed level of individual work units or jobs. These are left to be defined in Gantt charts, or similar planning devices, for the lowest level element in the WBS.

After the WBS elements have been developed, each element should be assigned a coded identification symbol. A simplified decimal coding system is recommended which will logically represent the WBS elements by levels, and with the associated upper level elements. Alphabetic or alphanumeric coding systems may also be used, if preferred by the project manager.

Typical WBS elements for a variety of project efforts are provided in Section D. These are provided as examples and guidance to the project manager in the development of the WBS.

WBS HIERARCHY DIAGRAM

After the WBS has been developed and the elements coded, a WBS hierarchy diagram may be developed. Figure I-1 shows such a diagram for the research

project example used above (the diagram is not complete, but is given for purposes of illustration). The diagram will prove useful in checking the developed WBS for logical element definition and completeness, and for assignment of element responsibility.

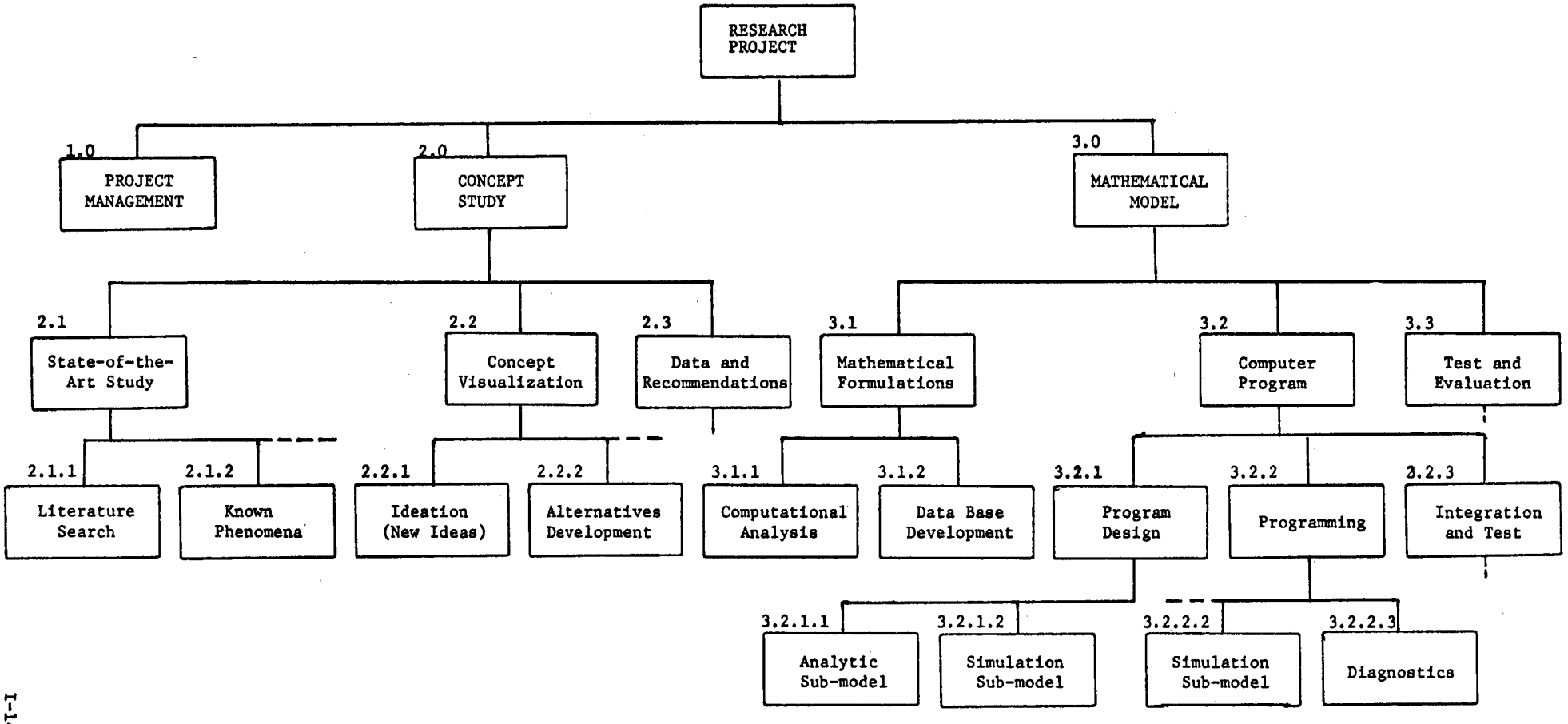

FIGURE I-1 EXAMPLE WBS HIERARCHY DIAGRAM

C. IMPLEMENTATION

☐ The foregoing methodology is generally applicable to all types of ERDA projects. In its implementation the project manager will be guided by the needs of the project in establishing the level to which the WBS is developed. Many projects of limited scope may require no more than two or three levels to the WBS, and for some of these the lowest level elements may indeed be finely detailed job definitions for individual effort. Other projects of a complex nature may require element definition to five or six sub-levels for some, but not necessarily all, of the first level elements. For the first cut at the WBS, the definition of effort by subdivision should be carried to the lowest logical level. This will provide a means for assuring that no element necessary for achieving the project objectives has been inadvertently omitted from the overall project effort.

☐ In developing the WBS, the preparation of a WBS checklist will prove useful to the project manager. The checklist should cover such items as:

- Based upon project objectives, Program Approval Document, SOW, etc., are all major end items identified?
- Is the effort represented by the WBS elements complete, compatible, and of proper continuity?
- Does the WBS represent a logical subdivision of the project effort?
- Are all functional and project requirements satisfied?
- Has assignment of single responsibility for each WBS element been identified?

- Do the WBS elements insure correlation with
  - Project/contract end items?
  - Project/contract line items?
  - Required data items?
  - SOW tasks?

- Are all elements amenable to cost estimation for the specific element defined?
- Are all elements amenable to schedule estimation for the specific element defined?

After the WBS has been developed and finalized, reporting requirements should be determined and procedures established. Periodic reports on progress of effort and cost status are necessary for management review, decision, and control. Techniques such as Cost/Schedule Performance Measurement, and Network Analysis provide such reports and opportunities for evaluation at appropriate levels.

Individual WBS's are usually developed well below the program budget level. However, any WBS structure used for planning and accumulating cost should be compatible with and coordinated with the ERDA budget and reporting classifications issued by the Office of the Controller.

This means that the elements at the lowest level of the WBS should accumulate into the budget and reporting classifications without the need for arbitrary allocation from within an element.

D. EXAMPLES OF WBS ELEMENTS

Typical examples of WBS element hierarchies are shown in Tables I-1 through I-4. The tabulations use a decimal notation for indicating the level of indenture for the elements of the WBS; e.g., the notation 1.0 represents the first first-level element of the WBS, 1.3 is the third second-level element, 1.4.2 is the second third-level element of the fourth second-level element, etc. Although the WBS hierarchies are shown in tabular form, a chart form (see Figure I-1) would be just as acceptable for the display of a project WBS.

The examples given are for a selected sample of possible categories of first-level elements. The examples of first-level and associated sub-level elements are not intended to be complete or all-inclusive. The intent of the tabulations is to provide guidance, and to show typical project WBS elements. The specific WBS elements for a given ERDA project, and the level to which the WBS is developed will depend upon the type and complexity of the project, and upon the needs and professional judgement of the project manager.

The identifying numbers assigned to the elements have also been used for tabulation and illustrative purposes. For a particular project, the numbering assignments may be arbitrary, in accordance with the needs of the project. The use of a decimal numbering system is recommended; however an alphabetic, or an alphanumeric system may also be employed.

For some projects, WBS elements shown as first level elements in the Tables may be subsumed under another first level element of the particular project, e.g., a math model, or software system may be sub-elements of a larger WBS element on projects which are large in scope and complexity. In other words, the WBS for a given project is to be tailored to fit the needs of the project in attaining the project objectives.

HARDWARE SYSTEM WBS ELEMENTS

1.0 HARDWARE SYSTEM

1.1 Subsystem A

1.1.1 Sub-Assembly A-1

1.1.1.1 Component A-1.1

1.1.1.2 Component A-1.2

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1.1.1.x Sub-Assembly A-1 Integration and Assembly

1.1.2 Sub-Assembly A-2

1.1.2.1 Component A-2.1

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1.1.3 Sub-Assembly A-3

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1.1.x Sub-System A Integration and Assembly

1.2 Subsystem B

1.2.1 Sub-Assembly B-1

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1.3 Subsystem C

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1.x System Test and Evaluation

TABLE I-1 HARDWARE SYSTEM WBS ELEMENTS

SOFTWARE SYSTEM WBS ELEMENTS

1.0 SOFTWARE SYSTEM

- 1.1 Support Software
  - 1.1.1 Compiler/Assembler
  - 1.1.2 Data Base Control
  - 1.1.3 Test Support Software
- 1.2 Operating System
  - 1.2.1 Executive
  - 1.2.2 I/O Control
  - 1.2.3 File Management
  - 1.2.4 Message Handling
  - 1.2.5 Central Management
  - 1.2.6 Maintenance and Diagnostics
- 1.3 Application Software
  - 1.3.1 Application Program A
  - 1.3.2 Application Program B
- 1.4 Documentation
- 1.5 System Test and Evaluation

TABLE I-2 SOFTWARE SYSTEM WBS ELEMENTS

SYSTEM TEST AND EVALUATION WBS ELEMENTS

1.0 SYSTEM TEST AND EVALUATION

- 1.1 Development Tests
  - 1.1.1 Engineering Design
  - 1.1.2 Sub-System Development
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  - .
  - .
- 1.2 Technical Evaluation
  - 1.2.1 Engineering
  - 1.2.2 Acceptance
  - 1.2.3 Reliability
  - 1.2.4 Maintenance
  - .
  - .
  - .
- 1.3 Operational Evaluation
  - 1.3.1 Integration
    - 1.3.1.1 Configuration
    - 1.3.1.2 Interaction
  - 1.3.2 Performance
    - 1.3.2.1 Sub-system
    - 1.3.2.2 System
  - 1.3.3 Field Demonstration
- 1.4 Test and Evaluation Support
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  - .
  - .
- 1.5 Test Facilities
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  - .

TABLE I-3 SYSTEM TEST AND EVALUATION WBS ELEMENTS

PROJECT SUPPORT WBS ELEMENTS

1.0 PROJECT SUPPORT

- 1.1 Data
  - 1.1.1 Technical Manuals, Handbooks, and Documents
  - 1.1.2 Scientific and Engineering Data
  - 1.1.3 Management Data
- 1.2 Operational Activation
  - 1.2.1 Site/Facility Construction
  - 1.2.2 Site/Facility Conversion
  - 1.2.3 Contractor Technical Support
  - 1.2.4 On-Site Assembly, Installation and Checkout
- 1.3 Product Assurance
  - 1.3.1 Quality Control
  - 1.3.2 Value Engineering
  - 1.3.3 Product Source Qualification
  - 1.3.4 Inspection
- 1.4 Logistic Support
  - 1.4.1 Integrated Logistic Support
  - 1.4.2 Spares and Repair Parts
- 1.5 Training
  - 1.5.1 Equipment
  - 1.5.2 Services
  - 1.5.3 Facilities
  - 1.5.4 Implementation

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TABLE I-4 PROJECT SUPPORT WBS ELEMENTS

E. SELECTED REFERENCES

☐ The following selected references are listed as sources of background management information pertaining to the WBS technique. A number of the references are not specifically concerned with the WBS technique, per se, but illustrate the variety of activities and interests that enter into project planning and may be considered in the development of the project WBS.

- NASA NHB (Draft Copy): "Handbook for Preparation of Work Breakdown Structures," September 1972
- MIL-STD-881: "Military Standard: Work Breakdown Structures for Defense Material Items," 1 November 1968
- AMA Management Report #74: "PERT, A New Management Planning and Control Technique," J. W. Blood, Ed. American Management Assn, NY 1962
- NAVAIR AR-59B: "Guide for Preparation of Management Portions of Technical Development Plans and Solicitations," 1 May 1972
- MIL-STD-499A (USAF): "Military Standard: Engineering Management," 1 May 1974
- AFSCP 800-6: "Air Force Systems Command Manual. Acquisition Management: Statement of Work Preparation Guide," 14 May 1971
- AFSCP 800-3: "Air Force Systems Command Pamphlet: Acquisition Management: A Guide for Program Management," 14 May 1971
- AR 70-17: "Army Regulation. Research and Development: System/Project Management" 19 January 1968
- MIL-STD-1521 (USAF): "Military Standard: Technical Review and Audit for Systems, Equipment and Computer Programs," 1 September 1972