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SPECIFYING MILESTONES FOR SOFTWARE ACQUISITIONS

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I Abstract

The establishment of project milestones for assessing progress is good management practice. Several government software management systems are available for assisting in the selection of the appropriate milestones and in specifying these milestones in the contract. A comparison of these systems shows they are similar; but there are significant differences that need to be understood so that the particular system chosen is used appropriately. The available systems are in need of modernization and each is deficient in some way. These limitations require that, for most projects, the user amplify, augment or tailor the fundamental precepts of the plan utilized. Special project considerations usually require additional tailoring, beyond that required for modernization.

II New Military Policy

The discussion on software management which follows is based principally on methodology currently being utilized by a majority of the agencies within the Air Force Systems Command. Recently the Department of Defense issued DoDD 5000.29[1], which indicates that more management attention should be given to the software embedded in major systems and to all related computer resources. The Air Force responded to this direction with regulation AFR 800-14, in two volumes.[2] The DoD document states that technical cost and schedule problems have been experienced with systems having embedded computer resources, and that an approach to the solution is to apply more rigid documentation and design review standards. AFR 800-14 supports this philosophy with specifics in Volume II by advocating the use of existing military standards. It is not clear that use of the system of existing military standards would totally solve the problems defined by DoD. It is clear that the system advocated in AFR 800-14 is not well codified and modernized anywhere in a management guide. Air Force Systems/Logistics Command Manual 375-7[3] provides such a guide but it is now seven years old.

The DoD requirement further states that this management attention continue throughout the system life-cycle. Although the early steps of the life cycle are extremely important, management attention should come into sharp focus during full scale development when the technical and procurement decisions are made which affect the most costly portions of the life cycle of the system. Program managers are expected to apply good management practices which include the establishment of project milestones, particularly during the full scale engineering effort. Milestones allow the manager to assess the progress of the project and to make decisions concerning future activities. For overall systems and for hardware systems, techniques for identifying milestones and for reviewing status at these milestones are well established. These principles have been extended to the software realm, but there is a definite lag in the formalization process and the resulting standards fail to keep pace with data processing technology. Air Force guide books and a replacement for AFSCM 375-7 are all in preparation presently and these will help in updating management guidance.

III A Frame of Reference

Government agencies have issued management guidance documents for the acquisition of software over the past several years. The basic intent of this discussion is to compare these systems and see what features are common (and hence indicative of being desirable) and where the systems vary. An understanding of the differences could lead to general improvements in the existing systems or could be source material for deriving a new system with broader application capability. Because Air Force policy is the author's background, that policy will be used as the frame of reference for comparison.

Life Cycle

The life cycle, as currently portrayed in Air Force management regulations, is shown in Fig. 1. As indicated previously, the cost driver for the entire life cycle is the set of actions taken during the Full Scale Engineering Development phase of the cycle. However, these actions are governed by the analysis and planning results of the Conceptual and Validation phases. In general, the management systems compared address the development phase only. The AFR 800-14 depiction of the various activities of the development phase also are shown on Fig. 1. The overlapping of the development phase activities, and their overlap with the life cycle phases is a variable depending on the project and the method of management. The overlap between the end of the Validation phase and the start of the Full Scale Engineering Development phase is critical, can affect the fate of

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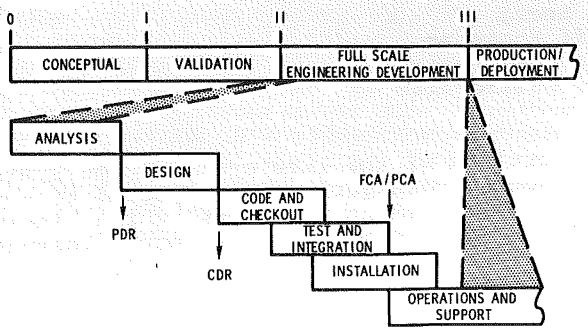


Fig. 1 Life Cycle Phases and Development Activities

the software development, and therefore will be discussed in detail later.

Key Documents and Events

The key documents chosen for the frame of reference are the following. The specifications and the Interface Control Document are described in related military standards and the testing documents and manuals are specified in Air Force data item descriptions.

System Specification
(Type A, MIL-STD-490)

Development Specification
(Type B5, MIL-STD-490
Part I, MIL-STD-483)

Product Specification
(Type C5, MIL-STD-490
Part II, MIL-STD-483)

Interface Control Document
(MIL-STD-483,
Appendix II)

Test Plan/Procedures
(DI-T-3703)

Test Report
(DI-T-3717)

Users Manual
(DI-M-3410)

Programming Manual
(DI-M-3411)

The data items have been selected from the Air Force repertoire consistent with the general Air Force viewpoint.

The key events which relate to the above documents are:

System Design Review (SDR)

Preliminary Design Review (PDR)

Critical Design Review (CDR)

Preliminary Qualification Tests (PQT)

Formal Qualification Test (FQT)

Functional Configuration Audit (FCA) (Sometimes extended to Formal Qualification Review, FQR)

Physical Configuration Audit (PCA)

These events are described and the requirements specified in MIL-STD-1521A.

The above documents will be used in the comparison with other management systems; and, where possible, the key events also will be related.

Embedded Systems

DoDD 5000.29 and AFR 800-14 address the management of computer resources that are embedded in larger systems. The management systems examined herein are not necessarily focused on this restricted viewpoint. In fact, the Air Force 300 series regulations address stand-alone automatic data processing (ADP) systems and these regulations have fostered management guidance documents such as DoD 4120.17M. The frame of reference for comparison is restricted to embedded applications, but something can be learned from ADP documents.

Data Item Relationships

The list of data items specified in DoD 5000.19-L[4] contains many near duplications for the same type of document. The data items indicated herein are Air Force items although others may meet project needs more precisely. In most instances, some tailoring is required to make each data item reflect exact project needs.

IV Management Systems Comparisons

General

The number of comparisons made herein is not exhaustive since ADP is not fully addressed. For instance, General Services Administration guidance[5] states that the benchmark program, a data system specification, the equipment performance requirements, and the workload requirements are the pertinent items to specify and monitor. These ADP characteristics are not always key in embedded systems. The management systems selected have either widespread use, or have a unique aspect which could be helpful in understanding the general management system requirements.

DoD 4120.17M[6]

As indicated above, this document is ADP oriented. This means that the System Specification is limited to data

processing. The Functional Description (FD) is the equivalent of the System Specification and describes, in management oriented terms, the operational capability desired by the user. Proposed methods and procedures are stated, quantitative performance values are specified, and the various inputs, outputs and processing requirements are defined. The management approach also is included and such items as the generation of a documentation plan, formal design reviews and configuration control are addressed.

The second document is the Data Requirements Document (RD) which addresses the data of the system: the input data and its source and procedures, the output data and its recipients, and the standard data of the system and its limits. The logical organization of the data is included. This item does not relate directly with the key documents list and can be considered unique, although its need exists in all systems. For an embedded system these requirements are most often part of the Development Specification.

The third document is the System/ Subsystem Specification (SS) which relates directly to the Development Specification. The basic difference is that segmenting the system into subsystem specifications is permitted.

The fourth document is the Program Specification (PS) which relates directly to the Product Specification. Generation of this document without the SS is permitted. It does not represent an overall description but rather incrementally defines the system through a collection of specifications. Preliminary documentation in notebook form is permitted.

The fifth document is the Data Base Specification (DS) which is a detailed description of storage allocation and data base organization. The focus here is an environment of many programmers utilizing the same data. Hence, standardization is necessary but is not restrictive. For example, there is no restriction on data format. This document, like the RD, is somewhat unique to ADP; but it is a necessary portion of detail design and can be assigned to the Product Specification.

The sixth document is the Users Manual which relates directly with a key document. It defines how to utilize the system, how to specify reports, how to prepare data and control information, and how to make use of outputs.

The seventh document is the Computer Operation Manual (OM) which provides the details of the computing center operating procedures. It is unique to an ADP environment but there is certainly a counterpart in embedded systems where operators are involved.

The eighth document is the Program Maintenance Manual (MM) which relates directly to its key equivalent. The document is addressed to the maintenance programmer. To some degree it ties together the data base documents and program specifications. The manual also provides for a test and Implementation Plan and for a corresponding test report. Descriptions of test materials and of the detailed procedures are included in the plan.

The unique document resulting from comparing 4120.17M with the key documents is the OM, which certainly is a necessary document and indicates that such a document should be on the key list. This is particularly true if the resident portions of the operating system are peculiar to the system of interest rather than a hardware manufacturer's standard.

The manual indicates that design reviews of the above documentation should be held but detailed guidance is not provided. The required documentation plan should specify not only the documents required but also the review process to be used.

Manual 4120.17M was recently superseded by DoD 7935.1-S, Automated Data System Documentation Standards. The Air Force has implemented these standards in new revisions to Air Force Regulations 300-2 and 300-12. These revisions were not included in the analysis.

WS 8506[7]

Weapons Specification 8506 set up an early standard for Navy procurement of software. A later Navy standard, SECNAVINST 3560.1 will be described below. WS 8506 is a documentation guide and does not provide much direction in the establishment of design review milestones.

The top document is the Computer Program Performance Specification (CPPS) which is used as the specification for procurement. It therefore relates to the Part I Development Specification.

The next three documents are the Computer Program Design Specification (CPDS), Computer Subprogram Design Document (CSDD) and the Common Data Base Design Document (CDBDD). Collectively, these describe the content of the Part II Product Specification; and, from a time phasing point of view, could be versions of the Part II. The CPDS, for instance, contains the design approach which generally is discussed at the PDR. In some approaches, a preliminary version of

the Part II is utilized to document the material to be discussed at the PDR.

The fifth document is really a package representing the physical aspects of the computer program. The Computer Program Package includes such things as source code in the form of cards (or tape equivalent), the object program on tape, a listing of the source code, and compiler listings. These items represent a set of products that can be specified for delivery in the Schedule of the contract.

The last three documents relate directly with their key documents counterparts: Computer Program Operator's Manual, Computer Program Test Plan, and Computer Program Test Procedures.

Exhibit 61-47B[8]

At the Space and Missiles Systems Organization (SAMSO), the Satellite Control Facility (SCF) found it necessary early in the development of that system to establish a software management standard because of the large number of software contractors interfacing with the system. Exhibit (Standard) 61-47B reflects the peculiarities of a fairly stable hardware environment, a large number of users of the system with varying needs, a continuing necessity to modify the application software to meet these changing needs, and a requirement to maintain a stable system configuration while modifications are being implemented.

The Exhibit also reflects the roles of two contractors supporting the system in addition to the development contractors. The first of these is the General System Engineering contractor whose function is to specify the development requirements for the new or modified software for the system. Because of the continuing nature of the SCF, the System Specification rarely enters the specification picture. Therefore, Milestone 1 of the Exhibit represents, for software, the equivalent of a statement of system functional requirements. Milestone 1 is used as the statement of requirements for contracting purposes.

The other unique contractor is the Integrating Contractor whose function is to bring together the products of various associate contractors and test these products at a system level. This integration effort is effected in blocks where each system configuration is called a Model. The user of the SCF system generally time-phases his application with either an existing model or plans on the basis of the approved changes in the next model. The Integrator prepares system level test plans and procedures for each model which are documented as Milestone 6. He also prepares operating instructions for each model which are documented as Milestone 7. His final product is Milestone 8 (which is also an event: turnover of the model to the Air Force) in which is documented the new (or deleted) features, the data base details, the unresolved discrepancies, the discrepancies corrected from the last model, and the ECPs implemented.

The Integrator is responsible also for Milestone 3 which is an interface control document (ICD). Because of the complexity of the SCF, it has been effective to publish and control the interfaces of the system as a separate set of documents.

This leaves Milestones 2, 4 and 5 for the associate contractor documents and/or events. Milestones 2 and 4 equate to the Part I Development Specification and the Part II Product Specification respectively. The Test Plan should be included with the Milestone 2 and the Test Procedures with the Milestone 4. Note that the contractor prepares both the Milestone 2 and the Milestone 4. Although the Milestone 2 and Part I equate in terms of content, the Milestone 2 is not used as the procurement specification.

The Milestone 5 is an event at which the associate contractor has completed all testing and has made a turnover to the Integrating Contractor for system testing.

It is interesting to note that the B-1 project chose this Exhibit as the basis for software management. Milestones I through V are essentially the same, although Milestone IV is detailed design only and the test procedures (and the related acceptance criteria) are placed in Milestone VI. Milestone VI concepts are reviewed at the PDR. Milestone VII, Operating Procedures, are somewhat more complex since the operator in this case is a B-1 crew member.

SECNAVINST 3560.1[9]

This Navy documentation standard is to be applied to the computer programs of combat systems which involve on-line interactive users. The number of documents which are specified is large, and not all documents would apply for a particular project. The system of documents is divided into four main categories: Operational, Technical, Test, and User.

The Operational group addresses the requirements from a user point of view and states the overall system requirements but is software oriented. An equipment specification group is included in the category. The Tactical

Operational Requirement (TOR) document is the principal document in the group and could be equated to a portion of the System Specification in the key documentation list.

The stating of system requirements is continued in the Technical category through two additional documents. The first of these is the System Operational Specification (SOS) which translates the user oriented language of the TOR to operational language. Hardware/software interfaces are defined and budgets are set for program storage and timing. The data communications protocols are defined as well as the associated procedures. Operational positions are clearly established.

The second system oriented technical document is the System Operational Design (SOD) and responds to the SOS with further detailing of the elements of the system. For example, input/output channels are detailed, message processing times are established, and supporting software is defined. The TOR, SOS and SOD collectively state the system requirements and permit the preparation of the required procurement, test and user documents.

Three documents are specified in the standard which relate to the Part I Development Specification. One of these, the Program Performance Specification (PPS), is mandatory and is used in the acquisition process for each computer system. If the overall system is comprised of several interfacing computer systems, several PPSs would be required. The PPS sets a configuration control baseline for programming efforts as does the Part I Development Specification.

The requirements in the PPS may, optionally, be expanded in two additional documents. The Function Operational Specification (FOS) defines each operator function and the functions of each piece of peripheral equipment. The interplay between the operator, the equipment (e.g., display consoles) and the processor are clearly established. The second optional expansion to the PPS is the Function Operational Design (FOD) which states the design required in operator terms, for the functions established in the PPS and FOS. In addition, simulations for checkout of design and for testing are detailed.

Three documents comprise the equivalent of the Part II Product Specification. The top document is the Program Design Specification (PDS) and is supported by design details for all the sub-programs in the Program Description Document (PDD). The design details of the data base are separately recorded in the Data Base Design (DBD).

Test Planning is segmented into two volumes. The Test Plan (TP) addresses the overall scope of the test effort, including management information on facilities, schedule and personnel. The methods to be utilized in assuring all specified functions are tested are stated. The details of the testing such as data constraints, limits of the hardware and software, and accuracy are related to the TP in the second document: the Test Specification (TS). Normally the TP and TS are treated as an entity. The testing procedures are a separate document and ultimately are published with related test reports. These items relate directly to the key documents.

A separate interface document is included called the Interface Design Specification (IDS). It normally is required when two or more data systems must interface and it defines the protocols for the message traffic. Each PPS should reflect the necessary IDS information.

On a technical level, an Operator's Manual (OM) and a Program Design Manual (PDM) are specified. The OM equates to the OM of 4120.17M while the PDM relates to the Programming Manual on the key list. On the user level two manuals are specified. One of these is addressed to the command level (Command and Staff Manual, CSM) and would normally be used by senior officers and planners. It is a broad treatment of the system functions but would provide senior personnel enough information to specify how the system would be utilized. A more detailed technical manual is provided for field personnel (System Operator's Manual, SOM).

This management system has the definite characteristic of attempting to involve the user more in the process, particularly in stating the functional requirements. This includes the operators, their tasks, and the devices which they operate. It details the design information more precisely. And it recognizes two classes of users.

Viking '75 [10]

This management system was utilized by the NASA Viking Project Office and was imposed on all software developed for use at the Jet Propulsion Laboratory. The system, like SECNAVINST 3560.1, heavily emphasizes the statement of requirements and the coordination and approval of these requirements at all levels of project control.

The general data processing environment where this system was used consisted principally of a large central processor in which the applications software of each of the various experimenters was required to execute and

to interface with the other experimenters' software. Interface control and integration of the applications packages, therefore, was a significant aspect of the overall task.

The first design document required is the Software Functional Description (SFD) which is prepared by flight operations groups. It relates to a higher level document called the Integrated Software Functional Design (ISFD). The details in the SFD principally are functional requirements of the pieces of the system and the interfaces between these subsystems. The SFD (and the ISFD) are equivalent to the System Specification.

To get the management approval for the design required for each software system, an interim document called the Functional Requirements Document (FRD) is prepared. The FRD translates SFD language into design oriented language to set the stage for the formal document which follows, the Software Requirements Document (SRD). The SRD is the equivalent of the Part I Development Specification.

The Part II Product Specification is encompassed in the General Design Document (GDD). However, the GDD provides a more complete package than the Part II. For example, a complete overview of the analysis conducted to arrive at the design approach is provided. It directly relates the functions of the SRD to the actual design elements (routines, modules, etc.). A work plan and schedule are provided as an attachment.

A supporting document for the GDD is the Software Data Base Document (SDBB). It appears chronologically slightly later than the GDD. It contains the table, buffer, file and constants definitions and structures necessary to define the design of the data base.

The testing is documented in plans and procedures (one volume) and is segmented into four classes of tests: a) programmer (for confidence); b) certification (logic and mathematical checks of output versus established inputs - generally done on the development computer(s)); c) user acceptance (a repeat of the certification tests on the operational computer(s)); and d) integration of the system. A separate document augments the plans and procedures called the Test Data Package (TDP). The TDP defines the nature of test data, where it resides, software used to generate test data, and any drivers needed to pass data to the operational software.

A Program Description Document (PDD) is used to collect all the materials necessary to maintain each system of software and is similar to the turnover and/or delivery packages of some of the other systems described.

Finally, a Users' Guide is provided by the system. The entire system has 12 identified milestones, each of which requires some sort of review or audit activity. The procedures and responsibilities are outlined in the document.

Comparison Summary

The following documents fall out of the above comparisons as unique and should be considered in the tailoring of any plan in use. In addition, if the plan of interest does not reflect some of the key documents, these should be considered also since most plans recognize the key documents in some form.

Data Base Specification

Computer Operation Manual

Computer Program Package

Integration Test Plans/Procedures

Integrated Program Package

Command and Staff Manual

Test Data Package

The Data Base Specification could be part of the Product Specification, but the fact that it appears in most of the systems as a separate entity justifies special attention. In data base oriented systems, the document serves many of the functions of the ICD.

There is no doubt that the Computer Operator's Manual is required, and it should have been on the key list.

The Computer Program Package is more of a contractual tool than a technical tool. It certainly is needed during delivery to specify the physical aspects of the software.

The Integration Test Plans/Procedures come from Exhibit 61-47B. These would be applicable when separate contractual effort is required to integrate associate contractor/agency products. The same is true of the Exhibit 61-47B Milestone 8 Integrated Program Package, which is the equivalent of the Computer Program Package but for the integrating contractor. Data Items exist for these test plans, procedures and the associated reports (T-3706 and T-3719). The Version Description Document (data item E-3121) is representative of the Program Package.

The Command and Staff Manual appears to be an important document for large complex systems.

V Requirements

No development project can expect success if the requirements for development have not stabilized and have not been completely documented. It is interesting to note the heavy emphasis on requirements generation in 3560.1 and Viking '75, which are recent documents. They reflect a growing awareness of the need to involve the user and operational organizations and to obtain their approval of the written requirements. In order to pin down the requirements, certain analysis milestones must be reached prior to start of development.

Development Requirements Deficiencies

The transition between the Validation phase and the Full Scale Engineering Development phase is depicted in Fig. 1 as a zone rather than as a sharp demarcation. From a requirements point of view, this is likely to be the case because the products of the Validation phase are preliminary for the Configuration Items. This means that the Part I Specifications for software may be incomplete, or at least not totally definitive.

The key product of the Validation phase is the System Specification which is reviewed and approved through the System Design Review (SDR). The secondary product is the Allocated Baseline which is embodied in preliminary Configuration Item (CI) specifications, or System Segment Specifications, the combined performance of which will meet the System Specification. For computer program Configuration Items (CPCIs), there is need for these to correlate exactly with the corresponding CI specification for the computer. If both the data processing hardware and software are to be developed for the system, the allocation of functions between the hardware and software which occurs during the Validation phase is, of necessity, imperfect. Core requirements are not always clear, allocation of some functions to hardware (say, in firmware) versus the software may not have been made, and the interfaces with personnel and other systems is seldom final.

Since the CI and CPCI specifications are the tools to be used for entering into the Full Scale Engineering Development phase, and because these specifications can be imperfect, the technical foundation for a contract is poor. Post contract award reviews are now being considered in which the equivalent of the SDR is conducted after the contract award to insure that the requirements are clear. On major systems, the software may get lost in the shuffle however. A study[11] conducted recently by the National Research Council Air Force Studies Board concluded that a separate contract to develop the "Detailed System Design Requirements," to be awarded after the Validation phase but before the start of design, was appropriate more often than not. Certainly the risk and technical analyses conducted in the Validation phase must, of necessity, attack the major problems of the system first. Data processing can be allocated an amorphous set of functions in this process because of its inherent "flexibility". Also the careful allocation process might stop here, resulting in poor tradeoffs between the data processing hardware and software.

Analysis Needs

Certain types of analyses are needed to complete the requirements. In addition to detailed technical descriptions of requirements, there are management oriented requirements that must be included. Hence the requirements development process must have a broad perspective. The following are a few examples of each. In general, milestones for completion of these activities must be established and the results documented before development is initiated.

Technical Analyses

- Functional Flows
- Hardware/Software/Firmware Trades
- System/Data System Interfaces
- Data Base Concept
- Processing Load (sizing, timing, through-put)
- Limits (anomalous and extreme conditions)
- Accuracy
- Critical Algorithms
- Language Selection
- Testability

Management Analyses

- Cost/Scope Compatibility
- Schedule
- Number of Configuration Items
- Programming Structure
- Standards and Conventions
- Development Facilities
- Government Furnished Material
- Maintenance Method

Reliability

Security

VI Special Technical Considerations

Introduction

The range of activities for completing the requirements picture must vary from having to do nothing (because the Validation phase completed the work) to a special contract (as advocated in the aforementioned National Research Council report). In general, the situation is somewhere between these extremes. In addition, the requirements of a contract are more extensive than the requirements of the computer program being procured; and these must be taken into consideration when establishing contractual milestones. Thus, more milestones develop out of the planning process than those previously discussed. Special ways of running projects also affect the milestone picture.

Necessary Products

The prime objective of the contract is to procure the principal operational item or items in a cost effective manner and in accordance with the specifications. In addition, however, all the supporting resources must be considered and planned for in the procurement. These supporting products can be categorized as tools and facilities.

Tools. If the life cycle needs of the overall system require the tools used in development, provisions must be made to document and deliver these tools. Under AFR 800-14, the Computer Resources Integrated Support Plan (CRISP) establishes these needs in the Validation phase. Tools include compilers, assemblers, utilities, test aids, test scenarios, test drivers and data, system drivers, documentation aids, simulators, code auditors, requirements tracers, pre- and post-processors, and library systems. The design, development, testing and delivery of these tools establish independent contractual milestones.

Facilities. The ability to develop and then maintain the software away from the operational environment is usually desirable, although final operational testing is necessary. The scope of the facilities required depends on life cycle considerations such as those set forth in the CRISP. Besides buildings and their environmental equipment, test facilities can encompass special hardware or software simulators, test generation software, and functional operational hardware. The procurement of these components establishes the third set of interrelated milestones.

Design Review

The standard reviews of MIL-STD-1521A are necessary. However, each project should examine its needs for special reviews. These reviews should be agreed upon and made part of the contract. For instance, a single Critical Design Review (CDR) may be unreasonable if the project is large. Orderly incremental CDRs make more sense. Of course, the subject matter and milestone attainment criteria for each of these CDRs must be established. In some cases a critical module, with long lead time needs, should be handled as a special case. The material to be provided at each review should be established. For example, according to 375-7, a partial Part II specification is an appropriate way of showing the design approach at PDR. Test plans should be available at PDR and test procedures should be reviewed and approved prior to testing. In general, reviews should be held according to project needs, but the review should be held when the material is ready for review and should not be dictated by schedule. Incomplete reviews, caused by strict adherence to schedule, can be sources of more significant schedule problems later.

Special Approaches

The standards and management plans normally applied in contracts are not always able to cope with all situations. In addition, they are deficient in dealing with new engineering approaches to software development. These aspects must be considered in project planning and adjustments made.

Builds. One approach, alluded to previously, and suggested by the National Research Council study, is that of planning the delivery of the total required capability in increments. The term applied to these increments in the study is Builds. Fig. 2 indicates the concept. Each Build should be capable of performing a useful function for the user. For example, Build 1 could provide a control and display capability so that operators could be trained on display devices using simulations for the remaining portions of the system. An additional payoff for this approach is the operational feedback into succeeding Builds which should insure user satisfaction. Criteria should be stated in the contract for defining the Builds. With Builds utilized, the complexities of the milestones of the contract increase and more care must be taken in setting these milestones. Of course, Builds should be planned for minimizing the throw-away design required for "stubs".

Structured Programming. If the decision is made to follow structured

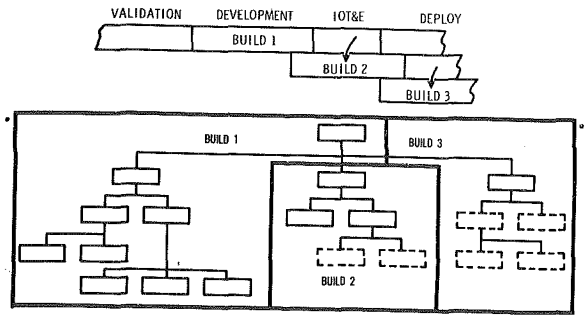


Fig. 2 Build Concept

programming, calling out the usual military standards requires that a certain amount of tailoring be done on these standards. For example, the "build a little, test a little" philosophy calls for incremental designs, tests and the corresponding reviews. This would be an entirely different schedule and the attainment criteria for the milestones would be significantly different. Since the ground rules for this approach have not been formalized in the military standards, tailoring is required.

Tailoring. Structured programming is only one area where tailoring may be required. There is general direction in DoDD 4120.21[12] that program managers should tailor all requirements to the minimum consistent with the stated need, and that the results be reported at DoD reviews. In the specific case of the modern programming techniques like top down and structured programming, MIL-STD-483, Appendix VI, must be tailored to require hierarchial design, execution order programming, use of only approved logic structures (or prohibition of unwanted structures like "go-to"), use of the HIPO method in preference to flow charts, use of comment cards (i.e., self-documentation), and limits on the size of modules. MIL-STD-1521A has to have corresponding tailoring.

Independent V&V. Verification and Validation is a term used with a multitude of meanings. In some cases it has been relegated to testing only, and was placed in that environment in AFR 800-14. More recently, however, there are broader definitions being used and different meanings applied to Verification than to Validation. This confusion is expected to resolve itself ultimately. However, the function must be addressed in procurement documents if the need exists. Therefore, it would be prudent to define V&V in the contract until a universally accepted definition is available. The "independent" aspect usually pertains to separate contracts which aid the project office in the review process or testing process or both. V&V can be tailored to the need. If help in reviewing design only is needed, define V&V as that and contract accordingly. If independent testing only is needed, that is what V&V is for that particular contract. But roles and responsibilities need to be clear and the needs of the V&V contract may impact the milestone schedule of the development contract, or vice versa. In addition, interchange of design information between the two contractors must be clearly set forth. The IV&V contractor can help the project office, but using him can complicate the planning.

Integration. The IV&V contractor is active during the associate contractor's development as described above. He, or a separate contractor, can become the integrating contractor in pulling all the CPCIs together into an overall software system. Or the integration function could be broader in pulling together the hardware/software system. Of course, above this level is the entire system assembly, usually done by the prime contractor. When integration is needed, the requirements should be established in the Validation phase and appropriate contractual relationships set up between the development and integration activities. Of course, additional milestones enter the picture, e.g., system data base freeze, compool freeze, integration test plans/procedures and interface control documents.

Other Approaches. Some additional milestones to consider, and which must be provided for in the contract, are periodic technical interchange (TI) meetings at which reports could be made on system engineering analysis. TI meetings are particularly effective when the specifications are not sufficiently clear. Separate reviews of test plans and test procedures would tend to reduce PDR and CDR duration. Preliminary Qualification Tests on critical items (but not on all modules) should be formalized and the attainment criteria documented. If Quality Assurance has been formalized on the contract, periodic audits may be of value and should be scheduled. The same can be said of configuration management audits. These disciplines assure, for example, adequate documentation and quality control of development and test tools.

VII Special Contractual Considerations

Introduction

Prior discussion has highlighted the need to insure that requirements are complete before contracting for development. AFSCM/AFLCM 375-7 says to handle the procurement in steps (a variation of the National Research Council concept) in which the first step is to complete the requirements. In terms of preparing contracts, means must

be found for taking care of this particular problem.

In addition to solving this basic problem, the contract must provide some of the products discussed below. Guidance in how to ask for and manage these items is needed, so care should be taken until adequate guidance has been documented.

Special Reports and Documents

AFR 800-14 has defined the Computer Program Development Plan (CPDP) as a key management tool. This document should be required since, as presently envisioned, it consolidates all pertinent software management information in one place. The CPDP asks for the contractor's view of the requirements (adequate, clear, testable, etc.) and his view of what priority various characteristics have, such as reliability, efficiency, portability, etc. This discussion should establish a frame of understanding between customer and contractor. The CPDP continues with detailed tasks and schedules, organizational responsibilities, manpower, facilities, engineering standards and methods, testing methods, and internal management controls.

The CPDP tends to become interrelated with other plans such as the Systems Engineering Management Plan (SEMP), Configuration Management Plan (CMP), Quality Assurance Plan, and Test and Evaluation Master Plan. For major programs, some logical compilation of the data from these plans must be effected to avoid duplication. The CMP should address (or relegate to the CPDP) control of the operational software, the tools, the simulations and the test materials. The QA plan should define audits which insure that the standards and conventions agreed upon are being applied. Adequate error reporting and control also could be a QA monitoring function.

The need for plans is evident and the need to update these plans during the period of performance may also be present. These activities add to the milestones already discussed.

Standard Requirements

Work Breakdown Structure. The WBS is used on most major systems by invoking MIL-STD-881. The level at which software sits in the WBS and the degree of sub-tiering must be determined on a project basis. The important thing is to get software at a high level so that it gets adequate management attention and the sub-tiering should be sufficient to provide management control.

Engineering Change Proposals. ECPs are almost a sure thing on any project, even if the requirements are well defined. The user may change the requirements or unforeseen events can cause changes. So the project should plan for ECPs and the necessary supporting activities. The review and processing of ECPs provides an additional spectrum of milestones. An effective ECP processing tool is the screening function mentioned in AFR 800-14. The Satellite Control Facility and the B-1 project both used this method with success.

A new Guide

Fig. 1 indicated the AFR 800-14 view of the phases of the development cycle. Based on the above discussion, as well as some recent studies,[13, 14, 15] it appears necessary to modify and expand Fig. 1. In Fig. 3 the development cycle is redrawn by first reflecting the requirements uncertainly. The Part I specification is finalized through system engineering analysis in which all the TBDs (to be determined) that remained in the specifications at the end of the Validation phase are removed. It is possible that changes of scope will evolve during these studies so the ECP process may be initiated early in the cycle. The analysis effort should continue at a reduced level after requirements resolution.

Once the Part I is authenticated by the customer, the preliminary design necessary to support the PDR may be initiated. The PDR approves the design approach, and the approach may be documented in draft Part II specifications. The Test Plan also should be approved at PDR. Interface Control Drawings should be approved as required.

The Detail Design period is when the code-to design information is generated and this is documented in a draft (without code dependent products like listings) of the Part II. The package is then reviewed at CDR along with the test procedures. Some detail design effort may be allowed to overlap the preliminary

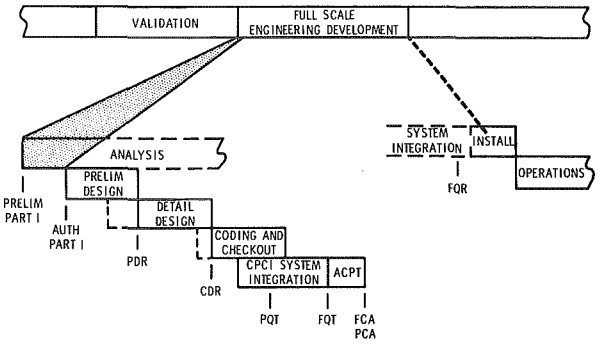


Fig. 3 Revised Development Activities

design to support critical or long lead components.

Coding and programmer checkout then follows, again with pre-CDR coding occuring where critical components are involved. Either here or in the CPCI integration phase, the PQTs singled out will be conducted for customer approval.

The CPCI integration phase culminates in acceptance of the Formal Qualification Test in the development environment. Functional and Physical Configuration Audits follow in the Acceptance phase. For a single CPCI, this would close out the development and the system would go into operations.

In large systems there may be several levels of system integration. During one of these levels of testing, it may be necessary to conduct the Formal Qualification Review. Unique site modifications would be dealt with in the Installation Phase. The contractor's responsibility should terminate with proper site peculiar versions of the software. The software product baseline could be established at this point.

VIII The Future

The proliferation of software management plans is under attack, at least in the Air Force Systems Command. An effort is being made to review the material discussed here and other similar documentation with the intent of developing a common process model. It is hoped that this effort and similar efforts will lead to a better understanding of the process, a viable method, and comprehensive guidance in use of the method.

IX Summary

For the prospective software buyer, there are many plans from which to choose. The tailoring of the plans discussed here should be carefully considered in applying any plan. As a minimum, the key documents and events should be imposed on the development with suitable updating to insure proven modern techniques are incorporated.

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