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77-1381

ELEMENTS OF THE COMPUTER PROGRAM DEVELOPMENT PLAN

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Abstract

Air Force Regulation 800-14 dictates that computer programs will be planned, analyzed, designed, coded, checked, integrated, tested, and delivered in accordance with a Computer Program Development Plan (CPDP). The CPDP is a management plan. This paper discusses the elements necessary to such a plan in terms of the classical management functions of definition of objectives, setting of goals, analysis and breakdown of work tasks, establishment of schedules, definition and establishment of organizational structures, allocation of resources, establishing standards, maintenance of motivation, accomplishing the work, and provision of management controls. The section of the paper relating to management controls specifically discusses status determination, management actions, documentation control, configuration control and quality assurance.

I. Introduction

Department of Defense policy (DODD 5000.29) states that computer resources (hardware and software) embedded in major weapon systems shall be managed as important subsystems and shall be treated as configuration items. Air Force policy (AFR 800-14) dictates that computer program configuration items (CPCIs) and the necessary support resources shall be planned, analyzed, designed coded, checked, integrated, tested, and delivered according to a Computer Program Development Plan (CPDP). The intent of this paper is to describe the nature of a CPDP and the elements which it should include. The concepts are the author's personal views and are not intended to define official Air Force policy.

The CPDP may be written and maintained by an Air Force development agency; or, if prepared by a contractor, should be used subject to the review and approval of the procuring agency. The CPDP must be compatible with the Computer Resource Integrated Support Plan (CRISP) maintained for the project by the Air Force. A realistic Computer Program Development Plan can be prepared only after adequate trade studies, life cycle studies, risk analysis, system definition and, where necessary, hardware and software prototyping have been completed. This will permit some degree of stability in the definitions of hardware and software configuration items, their interfaces, and estimates of required budgets and margins for memory, execution time, interfacing and communications.

The CPDP should be a living document which is the basis for the management of the computer program development effort. The CPDP should address and summarize in a single document all of the management issues. Where convenient because of size limitations, details may be incorporated by reference; but the references must be specific enough to indicate precisely the elements of the plan. Where a CPDP cannot be prepared as part of a contractor's proposal because the system definition has not progressed to the point of providing a sound basis for the plan, the contractor approach to computer program development should be documented and the CPDP prepared at some later time based on that approach and on the system definition.

II. Project Status

The CPDP should be based on previous technical work as well as on the project requirements. The project status section of the CPDP summarizes the definitions of hardware and software configuration items, their interfaces, the current functional allocation, and the required margins and budgets for memory, execution time, interfacing and communications. A summary of high risk and high uncertainty issues (technical, cost, or schedule) relating to computer resources must be presented. Approaches to minimize or overcome the risk and uncertainty should be detailed and back-up alternatives cited where possible. Where the risk involves long lead items, these must be enumerated and their status must be indicated. Trade and optimization studies yet to be conducted should be listed along with the computer resources which may be influenced by the studies. If the potential for major change is significant, further resolution of requirements is necessary before a project should function under a CPDP as defined in this paper.

A general functional flow diagram also should be presented. The relationship between mission objectives and computer resource requirements must be demonstrated. These relations, where possible, shall permit the evaluation of the effects of marginal changes in computer resource performance on mission performance.

The CPDP must define the objectives and goals associated with the computer program development. The objectives should be qualitative in nature, whereas the goals should be measurable and lead to fulfilling the objectives. For each CPCI, its planned allocation of function and its interfaces must be discussed. Budget goals for timing,

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memory, interface, and channel capacity shall be established. Margin for growth in these capacities both during development and future operation must be cited. The relative importance of such software characteristics as correctness, maintainability, testability, efficiency, portability, interoperability, etc., must be defined; goals in relation to these qualities must be cited.

III. Work Definition

The CPDP must define the work tasks required to achieve the objectives of the computer program development effort. The Work Breakdown Structure (WBS) should be compatible with the steps of analysis, design, coding, checkout, integration, test, acceptance and delivery for each CPCI and for each computer resource in support of software engineering tasks. Tasks associated with support functions (such as documentation, configuration management, data management, management reviews, etc.) must be included. The WBS should also address integration and test of CPCIs with separate test beds and within system tests including operational test where applicable. The number of levels of depth of the WBS should be sufficient to represent all developmental steps for all significant Computer Program Components (CPCs) in each CPCI and to accommodate all significant elements of the required support computer resources. If for some reason items are required for development which are not apparent in the WBS or not deliverable to the Air Force, these items must be enumerated, discussed and scheduled in the CPDP. As the work progresses, an updating of the WBS based on its accuracy of representation of the effort may be required.

IV. Work Schedule

A schedule of work tasks should be provided for each system CPCI and support CI or CPCI indicating the times of initiation, intermediate development steps, and completion. Specific, measurable milestones must be shown on the schedule. Availability of draft and final, formal and informal, documentation is also a schedule item. The standard military reviews and audits as well as the additional reviews and audits planned by the contractor should also be scheduled. Both summary schedules and detailed schedules are important. Where the system is to be delivered in increments (phases), the schedule for each phase should be shown and the relationships between phases described.

V. Activity Network

An activity network of computer program development efforts, compatible with the Work Schedule, should be prepared. Generally, where the development is affected by the performance of other agencies, contractors, subcontractors, or internal contractor organizations, the activity network is effective in identifying the critical events and interactions. Interfaces with other system developments which can impact the software development schedule must be indicated on the activity network. CPDP activities on the critical or near-critical paths must be identified. Special attention in the CPDP should be given to the adequacy of milestones and other measures of progress associated with these critical activities. Furthermore, to the extent possible those tasks and activity paths that might be most strongly influenced by changes in program requirements should be highlighted.

VI. Organization

The CPDP should describe the organizational structure designed to address the work tasks and maintain development on schedule. Important are explicit statements of responsibility and authority for each organizational element. Where authority is not commensurate with responsibility or where potential organizational conflicts of interest exist, the reasons for such must be stated and methods of assurance of proper task completion should be described.

Particular emphasis should be given to organizational interfaces and lines and methods of communication. The CPDP must define the relationships among requirements generation groups, computer resource development groups (including hardware development groups), test groups, independent or redundant verification and validation groups, documentation and library groups, configuration management groups, quality assurance groups, other contractors, sub-contractors, the procuring agency, the support agency and the user agency. The organizational structure should not seriously impede the flow of information to and from the various participating elements; however, special organizational structures to stabilize and evaluate requirements modifications should be considered.

Skill requirements in each organizational entity should be stated and persons meeting the requirements must be planned for those entities. Key skilled managers and employees should be identified. Their movement from one organizational element to another over the course of the development project must be planned. A plan for incentives, morale, and motivation to the timely attainment of goals is important. The training of employees initially and new to the project due to turnover should be estimated and planned. How such training will fit within the organization structure should be addressed.

VII. Resource Allocation

An allocation of manpower, skills, computer time, facilities, laboratories, test equipment, and other important resources must be made against the scheduled WBS elements. These allocations should be presented as a function of schedule time. Rapid increases or decreases in resource levels must be explained and justified. Availability of these resources must be discussed and planned.

Reallocation plans or alternative plans are important as they may be implemented during the project due to adverse outcomes of high risk development items. The ease with which manpower can be added to or deleted from the development effort and the organizational responsibilities for meeting the resource requirements should be identified.

When special security clearances are required, the CPDP should show in detail the plan (including

time delays to establish clearances and accounting for turnover) for meeting manpower and facility requirements.

General purpose computer time required for trade studies, analysis, design studies, simulation studies, data generation, proof of concept, verification, validation, certification, documentation, management control or other uses should be estimated. The availability and management of these resources must be addressed. When these resources are marginal, alternative plans must be presented in the CPDP.

Special purpose hardware and software resources should be discussed and scheduled in the CPDP. This must include government furnished items. Cost drivers and schedule impacts associated with these items must be explained and accommodated in the plan.

The approach to imposing the above requirements on subcontractors must be described.

VIII. Engineering Standards

The CPDP should identify engineering practices, standards, conventions, procedures, and rules for computer program requirements definition, design, structure, display, logic, input/output, data base, higher order language use, coding, checkout, documentation, data management, configuration management, testing techniques, quality assurance, maintenance, training, etc. Standards must provide for computer program flexibility, modularity, user understandability, and ease of maintenance/modification. Standards should also provide for conventions, restrictions, and rules that insure to the extent practical design and development visibility. Program source code itself must provide visibility by incorporating comments, formatting, clear mnemonics, and other coding conventions. Where security is required in processing data, the standards should be clearly defined.

Standards should be applicable to all computer program configuration items and supporting resources and should require to the maximum extent practical (1) a top down approach to design, (2) modularization of the programs by specific definable functions, (3) testability of each module, routine or subroutine, (4) simplicity of computer program interfaces, and (5) guidelines for integration and test.

The CPDP should indicate the mechanism by which the standards will be communicated to and imposed on the software development effort.

IX. Design Analysis

The CPDP must present the scheduled management plan for all computer program development including the steps of analysis, design, coding, checkout, integration and test, and including all computer resources in support of these steps. Management of data and documentation required in computer resource development also must be delineated. The data management activity should be compatible with the CRISP and must be maintained through the turnover of the system to the operational and maintenance agencies.

The CPDP must define design analysis tasks including the completion of required trade and optimization studies regarding computer resources. Computer resource design approaches should be analyzed, documented and provided for review. The objective of these analyses is to validate and refine the choice of computer resource alternatives, further define CPCIs and their interfaces, and provide a more substantial basis for software detailed design. Mathematical modeling, emulation, and simulation tools should be considered in this phase, and the CPDP should address the validity of these tools and their utility in subsequent phases of development, test, and, where required, operations and maintenance.

Updated estimates of memory, timing, interface, and channel capacity requirements along with margins for developmental growth and future requirements growth must be made. Program languages must be selected. The impact of subsequent hardware modification on software development must be estimated. High risk developmental items must be resolved and the Work Schedule or the Activity Network must be updated.

The results of design analysis efforts on computer resources should be reflected in revised Part 1 Specifications and approved at the Preliminary Design Review. The initial estimates of documentation and data bases necessary to support computer resources should be delivered for inclusion in the CRISP. The preliminary test concepts should be documented for review.

X. Design, Coding, and Checkout

The CPDP must provide for the design of all CPCIs in terms of their functions, internal and external interfaces, memory allocations, execution time allocations, channel requirement allocations, operating sequences, data base requirements and test requirements. Design should be based on clear statements of function traceable to system requirements. These requirements should include testability, reliability, integrity, flexibility, maintainability, interoperability, growth potential, and transferability. The CPDP should indicate the relative significance of each of these requirements so that appropriate design emphasis is given to each. The design should be "top down" where possible. Exceptions must be justified. Measures of design progress should be established for the various phases of the design. The CPDP should describe the mechanism of control both of the design and of the major design tools.

The use of specific design tools and concepts derived from analysis should be outlined. Design tools such as simulations, mathematical models, and emulations should, to the extent practical, be validated before use. Consideration should be given to using these tools during the integration and test phases of the development as well as during design.

Testing requirements must be refined and reflected in the design. CPC and CPCI interfaces must be designed to accommodate testing requirements. Furthermore, the CPDP should define the hardware requirements which accommodate computer program testability.

As part of the design effort, estimates of documentation requirements necessary for supporting developed computer programs are to be updated and provided to the procuring agency. Information required includes the identification of computer programs required to support system computer hardware and software, including diagnostic software for all computer resources, computer equipment and devices to facilitate software changes, documentation required to support each type of computer program and necessary procedures for reviewing and publishing changes, personnel resources required for supporting computer equipment and programs in the total system, and predicted level of computer program changes.

Measures to assure stability of the design process should be enumerated in the CPDP. Also, the CPDP should define the relation between the design effort and the configuration management plan as well as any independent design assessment efforts. The CPDP must provide for reviews including the Preliminary Design Review, the Critical Design Review, and internal reviews for each CPCI.

The CPDP should detail the procedures, steps, documentation, and milestones associated with coding checkout, and review of the modules comprising CPCs for each CPCI. Criteria and the mechanism for acceptance of modules for integration and test must be established including the roles of Configuration Management and Quality Assurance. Among the criteria must be adherence to software engineering standards, appropriate interpretation of function, properly defined inputs and outputs, adherence to timing, channel, memory and interface budgets, adequate attention to testing requirements, realistic checkout data, appropriate checkout tests, adequate interpretation of check results, and adequate documentation of program and checkout results. Planned static and dynamic software test tools must be described in the CPDP.

Where parameters are not available from the data management activities, the mechanism for obtaining these parameters and for informing the data management activity must be described.

XI. Integration and Test

Although top down design is required to the extent practical, in some cases coding, integration and test may best be implemented in some fashion other than top down. The philosophy of integration and test implementation and the reasons for it must be given in the CPDP.

The CPDP should describe the contractor's computer resource informal integration and test plans and procedures and how they lead to formal test and acceptance. The CPDP should assure that testing requirements are addressed sufficiently early in the development process so that testing is reflected in trade studies and computer resource designs. Long lead or high risk test items must be identified and planned to avoid schedule impact.

The CPDP must provide for definition of testing requirements which are traceable to system mission requirements. Test plans and test case definitions will reflect these requirements. The relationship between the test program and system reliability should be addressed. The CPDP must plan the testing of the CPCs and their integration into CPCIs. The Plan must further provide for CPCI tests to demonstrate compatibility with hardware, implementation of appropriate functions, satisfaction of memory, timing, interface and channel budgets, reliability, and overall performance.

XII. Formal Testing and Acceptance

The CPDP should provide the coordination and support of computer program testing during the formal system testing and acceptance phase of the system development. Interfaces with system test groups and operational test groups must be defined.

Training of test groups and system operations and users groups regarding computer resources (both operational and support) must be planned. The transfer of configuration management procedures, quality assurance procedures, standards, computer resource configuration items, and appropriate data and documentation should be described. The procedures to be followed during FQT and PQT should be stated.

XIII. Error Correction Control

The contractor should maintain written records of tests and their results. The CPDP should describe the planned methods of determining anomalies, validating errors, making modifications, and maintaining stability and control of the CPCI during testing. The relationships among the test, design, data management, quality assurance, change control, configuration management, and redundant assessment groups for error control activities must be described in the CPDP.

XIV. Management Controls

The means of management assessment of technical, financial, and schedule status must be defined in the CPDP. Criteria for determining management action should be established. Mechanisms for implementing and controlling management action should be described. The participation of the procuring agency in the visibility and control process ought to be clearly stated. The relationship to, and control of, subcontractors should be included.

1. Status Determination

Cost, schedule and technical status is assessed by comparison of plans with progress estimated through reports, documentation, interviews, meetings, tests, reviews and audits. The formal reviews and audits required for military standards are not sufficiently frequent to ascertain status

of software development with realism. The CPDP should define more frequent informal reviews, audits, tests, and other milestones which ought to appear on detailed schedules. The purposes of these should be described in the CPDP. Predefined criteria or measures of attainment must be presented in the CPDP for each milestone. Particular attention should be focused on those reviews and other milestones associated with critical path or near critical path development items. Periodic reassessment of the Activity Network and its critical path items is important.

The CPDP should define the qualifications required by those participating in reviews and assessing milestone attainment. The personnel participating ought to meet these qualifications. Continuity of the same qualified personnel in review participation is deemed desirable. The results of reviews, audits, and milestone evaluations must clearly be conveyed to appropriate decision makers. The participation of the procuring, using and support agencies in these informal reviews also should be defined in the CPDP.

2. Management Actions

Critical items of development behind schedule may be addressed by management actions of resource reallocation, schedule slippage, cost increase, or performance degradation. The CPDP should provide guidance and criteria for the appropriate actions under the appropriate circumstances. The CPDP should also provide for those circumstances and criteria when other Air Force agencies ought to be made aware of such problems in order to assist in setting priorities.

Among other issues to be addressed in the CPDP are those planned management actions which will maintain appropriate documentation quality, drive toward stability of requirements, clarify and stabilize interfaces, enforce adherence to practices and standards, provide for appropriate personnel and their tools, acquire and maintain the facilities for development, and generally provide for elimination of undue project complexity.

3. Documentation Requirements

Documentation is both a method of management visibility and control as well as an item to be controlled. Adequate computer resource documentation is an essential, but excessive documentation can be extremely costly. The CPDP should address the formal and informal documentation requirements of the computer program development effort, the purposes and levels of detail provided in each document, formats of presentation, methods of distribution and control, methods of update, and assurance that the disparity between documentation and system is minimized.

The availability of draft, interim and final editions of documents must be shown on schedules. Appropriate documentation must be available to permit reviewers time to study the documentation in advance of reviews.

4. Configuration Management

A plan and the organizational element associated with configuration management of computer resources must be defined in the CPDP. Excessive configuration control too early in the program will increase costs and inhibit good design by an overburden of paperwork and by decision bottlenecks. Inadequate configuration control late in the project will risk loss of configuration and encourage frivolous and uncoordinated changes. The configuration management plan should define various levels of control, and the response at these levels, the interface of software and hardware configuration management issues, criteria for proceeding to increased levels of configuration control, methods of validating requirements for changes of configuration, maintenance of independent master decks or tapes, and keeping records of change activity. Numbers and purposes of informal and formal configuration and status audits should be planned and scheduled.

The formal monitoring of time, memory, interface and channel budgets ought to be a configuration management function. Error and deficiency reporting and resolution during integration and test ought to be through the configuration management system. The CPDP should plan the interface of the configuration management process with the formal test and acceptance process, and should plan transfer of configuration management to the appropriate Air Force agency during the operations and maintenance of the system.

The role of the contractor's library in supporting the overall project should be described. Control of development versions of CPCs and CPCIs, handling of source and object code, control over test environments, relationship to modern programming techniques, and relationship to the Quality Assurance function should be detailed.

5. Quality Assurance

The CPDP must provide for a quality assurance organization independent of the development organization. The QA functions regarding the compliance with development policies, procedures and standards, documentation requirements and certification should be clarified.

The QA function includes audits to determine whether planned testing will demonstrate satisfaction of computer requirements and should assure traceability of requirements. The relationship between the QA function, the test and integration function, and the configuration management function should be defined in the CPDP.

6. Security Requirements

In instances where computer resources are being developed as part of a government classified project or require the use of classified information, the CPDP should indicate the method by which security is maintained while facilities, employees, data documentation and tools are brought to bear on the project in a timely manner. Interfaces among various levels of security must be discussed, and procedures to assure against violations must be presented.