SYSTEMS ENGINEERING FOR TRAINING SYSTEMS - A TEAM APPROACH

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ABSTRACT

This paper will present an approach to the conduct of the systems engineering process that can be applied to the development of both total training systems and training devices. The approach focuses on a team effort by the acquisition organization, the contractor and the ultimate using organization working together throughout the development cycle. Some of DOD's streamlining initiatives are applied to this process as well as the recently published DOD-STD-2167 and updated military standards.

The textbook systems engineering process must be adapted for training system development to coincide with the normally compressed acquisition phases of most large training systems. Several concepts found in DOD acquisition and systems engineering documentation are tailored for training systems programs and the development process, design reviews and testing discussed. This paper will show how a strong analytical process at the beginning of the contract effort can result in more objective testing at the end of the development phase. Recommendations for the conduct of major design reviews which emphasize the purpose of each review and utilize naturally evolving documentation will be made. An integrated process to improve the efficiency of training system development will be outlined using a team approach.

This approach, in order to be successful, will require all parties to adopt new methods of doing business with more freedom and flexibility for the contractor and less involvement in the design details by the acquisition organization. This also means some checks and balances must be defined and implemented. Throughout the paper several basic principles will be emphasized along with a proposed implementation.

INTRODUCTION

The systems engineering process was established to deal with multifaceted and complex development efforts in an orderly fashion and is a central fixture in the evolution of a system. Much has been written about how to employ this process for classical development programs and about the tools available for use in this process. This paper will discuss the systems engineering process in light of the training systems development environment and provide a recommended approach to this systems management problem. This paper will apply the DOD streamlining initiatives and adapt recently released updated standards, e.g., DOD-STD-2167, MIL-STD-1521B, etc, to the training systems development process. The System Engineering Management Guide developed by the Defense Systems Management College was also used as a guide.

A basic process is presented in this paper that must be further tailored for each specific program application. Similarly, this process can be adapted to the development of Aircrew Training Devices (ATDs). Examples cited in this paper are based on the Air Force development of a training system which includes an ATD of the complexity of a weapon system trainer (WST), e.g., B-52 WST, B-1B WST, F-16 WST, F-15E WST. Some of the ideas presented in this paper have been employed on some programs to various degrees. This paper brings many ideas together and integrates several concepts. All of the principles that have historically dealt with hardware and software can be tailored to address all the elements of a training system. For example, specifications can be written and technical reviews can be held on courseware and academics as well as hardware and software. The basic concepts and proposed implementation presented in this paper can be scaled to both ATD and total training systems programs. The systems engineering process is a central item of the systems management effort employed throughout the life of a program. However, this paper will emphasize the development phase and will highlight areas where the proposed approach has high potential payoff.

GENERAL PHILOSOPHY

The basic philosophy employs a highly structured but flexible systems engineering methodology that stresses a complete requirements analysis phase before the full scale design phase, with mutual Air Force and contractor agreement on the design at specific milestones. A relationship which encourages open communications and the early identification and resolution of problems is strongly encouraged so that the total resources are focused on a team approach to the development process.

This same philosophy is fundamental in the preceding front end analysis (FEA) phase. There must be a concerted effort to make sure the FEA and development phases are consistent. As explained later, one of the ideas of the proposed implementation is to give the development contractor more flexibility and authority to optimize the training system design by only specifying hard core performance requirements.

The basic approach is to implement a strong planning function at the beginning of a program. This applies to the Air Force's approach to the program as well as to the contractor's plan for implementing the contractual portion of the development effort. Program plans should describe specific implementations of the following ideas, which are the basis of this paper.

a. More contractor responsibility for the control and management of the development effort.

b. Less Air Force involvement in details of the system development process.

c. Air Force and contractor agreement on how the contractor will implement the development process through documented plans.

d. Increased emphasis on completion of requirements analyses before the detailed design process is begun.

e. Early emphasis of testing through the definitization of test requirements.

f. Application of selected MIL-STD-2167 milestone documents to form an agreed to allocated baseline which is an expansion of the contractual performance requirements.

The intent is to form a close knit team between the Air Force and contractor. More responsibility is given to the contractor to expand the original contractual functional baseline into a more definitive set of design requirements. The Air Force must become less involved in program details but be prepared to insert itself into the program when the contractor deviates from agreed to plans and baselines. The Air Force also must sign up to the expanded requirements baseline prior to the commencement of the design phase. This should result in the early identification of problems associated with the interpretation of the original performance requirements and also provides an expanded set of definitive test requirements. This process also encourages early cooperation of the contractor, aircraft manufacturer, user and acquiring agency in mutually working out design requirements details. Lower level requirements are derived from the original functional baseline (contract specification), the actual aircraft performance, how the aircrew interacts with it and its environment, and how the system will be employed in actual training scenarios. While the contractor has the lead responsibility for collecting all this information and synthesizing an implementation, the Air Force must provide much of this basic information as inputs to the analyses.

It may appear that this lack of detailed requirements leaves the scope of the contract wide open. However, this is not the case. Most of the things to be decided upon do not affect the scope of the analysis or design efforts but do provide indications of preferred approaches and more specific information to make tradeoff decisions. New out of scope requirements are identified early and can be incorporated prior to the onset of the intense design phase. This cooperative effort can also lead to a synergistic effect and provide the contractor a higher level of understanding of the users specific needs and the intent of many of the Air Force's requirements. Subsequently this will lead to more objective contractor reviews of their own design implementation.

IMPLEMENTATION APPROACH

Basic Guidelines

The suggested implementation is based on several principles which are reiterated throughout this paper. These are:

a. A top down design process with full requirements analysis before design implementation. Coupled with this is traceability of all requirements.

b. An iterative systems engineering process which incorporates provisions for changes to requirements.

c. A baseline control process which provides for the expansion of performance requirements into a set of design requirements and ultimately final product definition.

d. A series of technical reviews based on the premise that no review will be conducted until everything is ready for the review.

e. A bottom up integration and testing process based on the requirements established in the allocated baseline.

These principles, on the surface, appear to be similar to those which have been written about and employed before. This paper, however, utilizes them with some different thoughts and emphasizes them with a philosophy not normally exhibited on past ATD programs. The next few paragraphs summarize the basic acquisition approach that is discussed in more detail in subsequent sections.

Training systems generally do not follow the classical phased approach normally used in large weapon system acquisitions. The primary reason for this modified acquisition approach is the heavy dependence on the aircraft system definition and development profile. In general, the training system or ATD effort must start later and be completed earlier than the basic aircraft development effort. Thus, some compromises must be made. Figures 1a and b compare the program phases. For training systems the second and third phases are typically consolidated into a front end analysis (FEA) phase and the last two are often combined into a single development and production phase. Thus, the major reviews e.g., Defense System Acquisition Review Council (DSARC), which result in major decisions and the associated system level requirements documentation are not formally accomplished.

Because of the limited number of systems acquired and the weapon system deployment schedule the development and production phases are often combined in a single contract. The FEA conducted by the Air Force does not provide all the systems engineering documentation needed to support the development of the top level performance specification. This is a manpower intensive effort and it therefore, makes sense to include this as a contractor task. Therefore, a major task that should be conducted early in the contract effort is to perform a complete functional and performance requirements analysis to result in the complete documentation of all system requirements. This task should include the contractual requirement for complete traceability so that the source of lower level requirements can be determined. Following the identification of the requirements the design implementation can begin with the confidence that requirements changes will be minimal.

A baseline control process should be implemented using the normal functional, allocated and product baselines. The key difference in this proposed approach is the method by which the allocated baseline is controlled. The contractor should take formal control (subsequent changes require configuration control board action) just prior to the Preliminary Design Review (PDR) with the Air Force taking formal control at Critical Design Review (CDR). This forces the contractor to do a thorough job in establishing the allocated baseline but leaves him the freedom to change it without formal Air Force approval. At CDR the Air Force should take control of the allocated requirements baseline so that the contractor can change the design implementation under his own control but requires Air Force approval to change requirements for the design. This allows for freedom early in the program when it's needed but restricts changes as the design progresses. This results in the Air

MISSION NEED DETERMINATION	CONCEPT EXPLORATION	DEMONSTRATION VALIDATION	FULL SCALE DEVELOPMENT	PRODUCTION DEPLOYMENT
AIR FORCE	CONTRACTORS	CONTRACTORS	CONTRACTOR	CONTRACTOR
	DSARC I	DSARC II	DSARC III	
BASIC MISSION ANALYSIS	STUDIES ALTERNATIVES	SRR, SDR PROTOTYPE ANALYSIS SYNTHESIS TRADE STUDIES	PDR, CDR, FCA DESIGN TEST EVALUATION	PCA

FIGURE 1A CLASSICAL WEAPON SYSTEMS ACQUISITION APPROACH

MISSION NEED DETERMINATION	FRONT END ANALYSIS	DEVELOPMENT/PRODUCTION
AIR FORCE	AIR FORCE	CONTRACTOR
BASIC MISSION ANALYSIS	STUDIES ALTERNATIVES TOP LEVEL ANALYSIS	SSR, SDR, PDR, CDR, FCA, PCA DETAILED ANALYSIS SYNTHESIS TEST EVALUATION

FIGURE 1B TYPICAL ATD ACQUISITION APPROACH

Force and contractor agreeing to interpretations of high level requirements and the aircraft performance baseline along with the establishment of a definitive test requirements baseline.

The entire process is iterative since changes will occur and the need to correct mistakes will arise. This process also allows for aircraft changes to be incorporated in a systematic manner and provides for the flexibility for the simulator to include incremental software releases as an integral part of the program. The technical review process is modified to include concurrent Air Force and contractor reviews of milestone documentation with provisions for resolving most discrepancies prior to the formal review date. Thus, the emphasis of the formal reviews can be to resolve problems since the essence of the design discussions has already occurred. It should be noted that the review is actually conducted over a period of time.

A fallout of the allocated baseline approval milestone is establishment of a detailed set of test requirements below the system level. This baseline will provide the basis for less Air Force involvement in detailed testing but also provides for this level of testing if problems are discovered at higher levels of Air Force testing. Thus, the contractor is responsible to assure that all tests are satisfactorily completed in accordance with the approved allocated baseline.

All of this is tied together through a set of contractor developed plans which state how the contractor will conduct the program. The Air Force approval of these plans indicates a level of agreement which interprets the statement of work tasks, referenced requirements documents and internal company documents for the conduct of a specific program.

The following sections expand on the principles just summarized.

Program Implementation Plans

One of the foundations of this recommended approach for developing a training system is to document the methods to be used in running the program in a series of plans. The Systems Engineering Management Plan (SEMP) is the overall controlling systems development document. This plan should describe the organization, how it operates and how it interfaces with other contractor and subcontractor groups. It should also describe how the systems engineering process is to operate for the specific program taking into account any unique program aspects and the basic company organization. It should be written so that it can be a reference document for the contractor and Air Force alike. It is essential to have a program specific handbook that describes how the engineering function will be conducted so that lost time due to false starts is minimized. The SEMP should reference all other plans dealing with the systems management process but not repeat information contained in the other plans. The SEMP should describe the processes to be followed and products to be produced along with examples. The SEMP must be completed very early in the program so that it is available for the working level to use. This is essential because the systems engineering function is extremely important at the beginning of the program since its products lay the foundation for everything that follows. It also shows how all portions of the system development process fit together. While the initial version of the SEMP should address the entire life cycle of the effort, it may be necessary to expand some sections later as more specific information becomes available. For example, the items identified for technical performance measurement tracking may not be fully identified until the top level design is established and the exact approach to all integration and testing may not be determined until some specific design approaches have been selected. The point is that the SEMP should not become stagnant but should be periodically revised and expanded as the program progresses.

This same philosophy applies to the Configuration Management Plan (CMP), the Software Development Plan (SDP), Hardware Development Plan (HDP) and the System Test Plan (STP). All of these documents should be written to be used by the contractor as well as the Air Force. The Air Force must insist that these plans be followed since approval indicates an agreement on how the program is to be conducted. These plans should address how all the disciplines and functions are to be implemented, and deal with such things as multiple baseline control, requirements traceability, change control process, etc.

System Design Process

Another principle of this proposed systems development approach is that all requirements are identified and documented before the design process begins. In the past, most ATDs have been in the detailed design phase before all the requirements were fully definitized. As additional requirements were defined, the design had to be changed, sometimes significantly. Complete definition of requirements prior to the onset of the design effort will result in a longer period of time prior to PDR but there are many benefits to be gained. The purpose is to identify all design requirements and interfaces for lower level elements before the full blown design phase begins. Since few requirements changes are then expected, the design integration and test phases may be shorter than in the past. Thus, the net effect is no increase in schedule.

The requirements analysis process is very different than what has been done in the past. The contractor has the latitude and responsibility to refine the original contract performance requirements. The Air Force prepared system specification contains top level performance and functional requirements. It also contains references to aircraft performance capabilities and to aircrew tasks. The contractor must analyze these top level requirements, derive lower level requirements and allocate them to lower level elements. This is analogous to the allocation of system reliability requirements to subsystems and subassemblies. This can be done through discussions with the users to determine how they intend to use the training system, better understand the intent of the top level requirements, better understand how the actual aircraft performs and interacts with its surrounding environment and how the aircrew uses the aircraft to perform its mission. Other results of this analysis effort lead to the definition of specific support requirements including software modification, mission generation, data base generation, courseware content requirements, etc. It is desirable to reflect the results of the initial analysis in an operational concept document. This would allow the user to evaluate the contractors intrepretation of the many inputs from various sources and compare it to their original ideas.

This requirements analysis process may result in a need to change the functional baseline specifications. The Air Force must be receptive to this possibility since it is based on much more in-depth thought and may result in a more optimized design implementation. These derived requirements need to be individually documented on requirements allocation sheets so they can be readily handled at lower levels. This process exposes interfaces which can be captured as requirements, may result in single top level performance requirements being allocated to multiple lower level requirements and forces interpretations to be made and documented. The review of the aircraft design criteria data (aircraft performance descriptions) must now be done earlier than in the past. This forces interpretation of the data and identification of problems early in the program which can be ironed out prior to the existence of a design. Because some of this effort is done earlier a means to deal with unavailable data must be established (this will be discussed later).

A parallel process that lags the requirements analysis process is the systems synthesis process. This begins shortly after the requirements analysis is in full swing. As requirements are allocated to lower levels the system design begins to take shape. The basic technologies applicable to the design solution are known based on the top level requirements. The synthesis process assembles related requirements to form functional elements. Often these elements are based on experience and the functional grouping in the aircraft. This identification of elements that make up the system must also be documented. Thus, as more requirements are identified they can be allocated to synthesized functional elements. This synthesis process is iterative and several alternative concepts may be compared in a trade study before one is selected.

The analysis and synthesis processes can result in massive amounts of data which must be traceable so the history of any requirement can be determined at a later time. For a large training system, the only practical solution is a computerized data base. This traceability process should reduce later surprises (particularly at CDR or even during testing) since it is essential for the Air Force to review the final product of these processes - the allocated baseline. This early determination of how the aircraft system really works and precisely how the user intends to employ the system can be very enlightening. Similarly, the functions that need to be performed to generate a mission, generate and modify data bases and other support functions are identified. The user and aircraft manufacturer are integral parts of this process since they are the source of much of the information and they must be a part of the review process looking at the products. This forces disagreements into the open at an early stage and has a mutual benefit since the overall impact is minimal because detailed design has not yet begun.

Figure 2 shows the analysis and synthesis processes leading to the allocated baseline. Note the iterative analyses and the point where synthesis actually begins. Each CI and subsystem includes a complete definition of its function, performance and interfaces.

By having an orderly requirements and synthesis process in place it is possible to isolate problem design areas and not impact the entire schedule. This is particularly beneficial when complete aircraft performance data for a specific function is not available when needed. An incremental release of the areas affected can be incorporated into the program as a natural process. This allows a separate development effort to be completed using the same documentation process and tools as the mainstream configuration. The end result is a baseline configuration change along with an updated version of the software incorporated during the system integration phase or possibly subsequent to completion of the initial test period. The point is that if all the program plans and tools are initially established to handle this situation the actual implementation is straight forward and treated just like the rest of the program.

Technical Reviews

There are requirements for the contractor to provide program management reviews and status reports to the Air Force. These should be scheduled as required by the contract but be kept functionally separate from the technical reviews discussed in MIL-STD-1521B. The reason for this is to keep the objectives of the review in mind throughout the review and the objectives for technical and management reviews are normally different. The remainder of this section

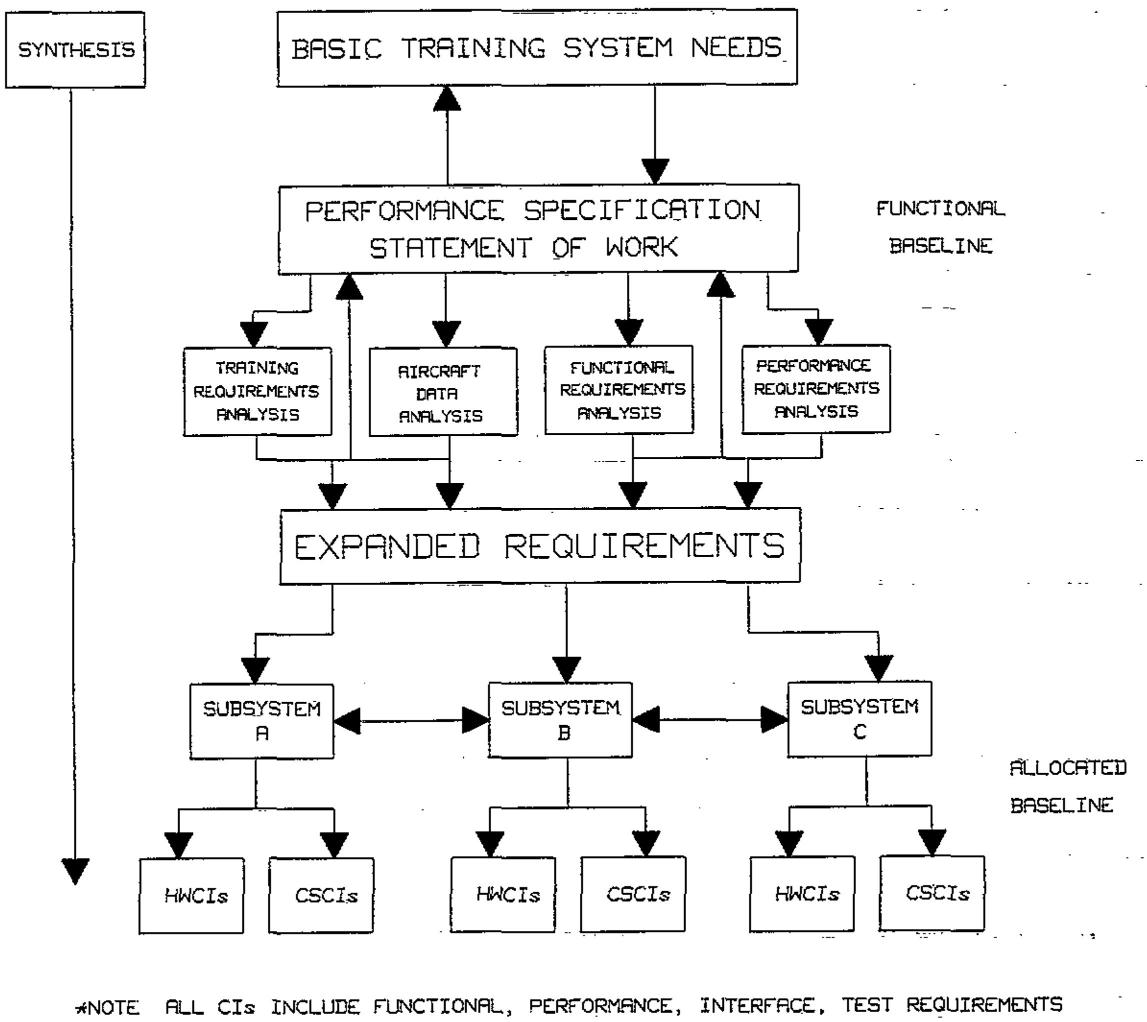

FIGURE 2 ANALYSIS AND SYNTHESIS PROCESS

discusses a modified approach to the conduct of these technical reviews. This modified approach is based on the premise that the contractor is responsible for the development of the training system and thus the review is conducted not just for the Air Force, but for an expert review group consisting of the contractor, aircraft manufacturer, Air Force and others as required. It is incumbent on the contractor to establish checks and balances in his normal development process. This is often accomplished by conducting walk-throughs, hand offs and other forms of a somewhat formal process. How this is accomplished and what it is called can vary depending on the company organization. In this paper it is assumed that various parts of requirements analysis, design, manufacturing and coding are done by different functional groups and that these groups will make sure the previous tasks are complete before they accept responsibility for their task. The hand off process needs to be tailored for a specific program and the Air Force considered as an extension of the review group.

Each review should have success criteria established which is based on MIL-STD-1521B but tailored to the program. The System Requirements Review (SRR) and System Design Review should be conducted on the entire training system at one time. This is possible because the depth of these reviews is typically less than some later reviews. Subsequent reviews should be conducted on lower level elements in-depth and include high level subsystem and system reviews to serve as summaries and to assure open action items and overall system considerations are resolved. A major requirement is that no review should be held until the contractor is ready to conduct a complete review and satisfy all of the success criteria. Figure 3 shows an example of the review process for a program. Note how the reviews are broken into smaller scope pieces as the requirements are allocated, and then brought back together as the system is integrated and tested.

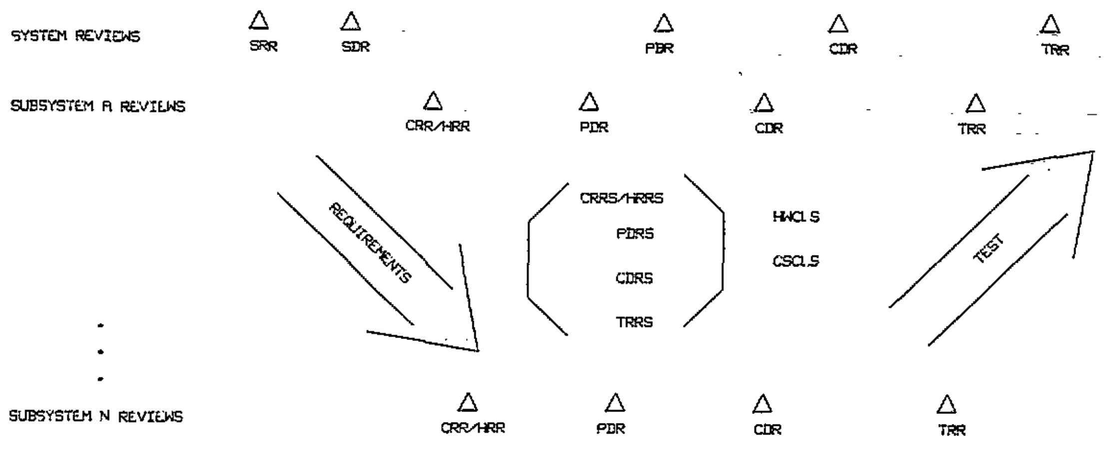

FIGURE 3 TECHNICAL REVIEW PROCESS EXAMPLE

One measure of readiness for a review is the adequacy of the documentation in terms of completeness, correctness, and its acceptability for hand off to another functional contractor group. The documentation is an indication of the thoroughness of thought and completeness of communicating ideas to someone else. It must be emphasized that the documentation should be used as a tool in following a structured process and it should not become the central issue itself. It is in the contractors best interest to delay a technical review rather than compound problems by pressing ahead and putting more pressure on a subsequent review or worse yet, have the Air Force assert itself by pointing out the agreed to SEMP criteria was not adhered to. This only causes more work for everyone in the long run. Subsequent paragraphs summarize each of the major technical reviews and relate them to milestone documentation identified in DOD-STD-2167.

The following general process is proposed for the conduct of these technical reviews. It should be noted that the formal review is the culmination of a period of time when most of the hard work is done, preceding the scheduled review date. This review period (normally about 30 days) can be conducted somewhat informally and in small groups. The review itself should be more formal. Prior to the formal review (30 days for example) the contractor should make available all the milestone documentation required for that review along with supporting documentation. During a 15-20 day period the documentation is reviewed by the Air Force, contractor and other members of the expert review group with questions written and submitted to the contractor focal point. Written responses are required for all questions. At the formal review the contractor responds to each open question. He also summarizes the specification or design as appropriate. There is no need for a detailed stand up presentation of the design since this task was accomplished prior to the formal review. In this way premium time can be spent on the tough problems. However, there is still a record of all questions with responses no matter how trivial. With this approach, more detail can be covered with a very small group of those interested in that level of detail. By strictly adhering to established standards for formal hand offs within the company there is also some assurance that the contractor will police himself. As a result of this process, a minimal number of open items should remain. A coordinated position should be established and closure plans agreed upon for any remaining open items.

System Requirements Review

The System Requirements Review (SRR) is to ascertain the adequacy of the efforts in defining system requirements[3]. It should be conducted subsequent to completion of the initial program planning (SEMP, SDP, CMP, etc) but before a significant effort has been put into the detailed requirements analysis. The functional baseline should be affirmed or action established to modify it based on the result of the top level requirements analyses. The plans for completing the detailed requirements analyses and initial system synthesis should be reviewed, e.g., aircraft data gathering and its analysis, training analyses, planned trade studies, etc.

System Design Review

The System Design Review (SDR) is to

evaluate the optimization, correlation, completeness and risks associated with the allocated technical requirements. This review should be conducted when the majority of the requirements analysis process has been completed and the synthesis process has resulted in the allocation of requirements to subsystems[3]. This can provide a good indication of how well the system engineering process is functioning and identify problem areas that might impact subsequent milestones. The documentation to be reviewed should include subsystem requirements specifications, requirements allocation sheets, supporting reports of studies and trade studies, functional block diagrams, interface diagrams, etc. Subsequent to this review, the elements of the training system can be more independent in terms of how they are treated in the system development process. Therefore, this is a significant milestone to assure that system level problems have been identified and resolved. This review also provides a good indication of how well the allocated baseline is being identified.

Hardware Specification Review /Software Specification Review

The Hardware Specification Review and Software Specification Review (HSR/SSR) is to evaluate the allocation of performance and design requirements to hardware and software configuration items (CIs)[3]. It should be conducted for each Hardware CI (HWCI) and Computer Software CI (CSCI) when all requirements have been allocated to it and it is ready for hand off to the design group. This is a very significant milestone for several reasons. First, a formal hand off is required signifying that preliminary design is ready to begin for that CI. Second, this hand off indicates agreement between the systems and design groups that the requirements documentation package is complete for that CI. Third, the allocated baseline is formally established for that CI and any changes to the HRS or SRS requires formal change control action by the contractor (see later CDR section on allocated baseline control). Fourth, the Air Force (user and acquisition organization) concurs with the contractor that the HRS and SRS represent the correct interpretation (based on known information at the time) of the intent of the contractual performance requirements (see the CDR discussion for additional information). Fifth, the test baseline is definitized by including test criteria and test cases for the allocated baseline requirements.

If the aircraft data describing a particular function is incomplete or just not available, some special action is required. This is most likely to occur for an aircraft system that is still in development. In cases where this occurs there is normally enough information available to adequately bound the simulation requirements for that function even though the specific data values are not available. The aircraft systems must be mature enough that predictions of performance and preliminary bench test data are available along with functional requirements from equipment specifications and drawings. Thus, HRS and SRS documents may have some holes but they can be adequately bounded by defining (assuming if necessary) interfaces with unknown internal functions. There is a point in time in the actual design phase when all this information is needed but the risk with this approach to buy more time is minimal.

Preliminary Design Review

The Preliminary Design Review (PDR) is to evaluate the top level design of each HWCI and CSCI against the allocated baseline previously established [3]. This review may be held for several CIs together if they are closely related. The top level design documents and plans for the detailed design phase should be reviewed. Plans for the test and integration phase of the program should also be reviewed based on the allocated baseline requirements established at the previous review. If necessary, the allocated baseline should be updated (note that this is a formal change action by the contractor). In some cases subsystem level reviews should be held and a total system summary should always be included. These additional reviews will help to tie individual CIs together to provide a total system and/or subsystem viewpoint of the design.

Critical Design Review

The Critical Design Review (CDR) is to evaluate the detailed design of each CI against the allocated baseline [3]. Part of this evaluation is the review of the specific test criteria and test methods planned for each CI. Additional subsystem and system level reviews should also be planned. These additional reviews provide not only a look at the entire system from a design viewpoint, but also from a test viewpoint since significant testing will be conducted at the subsystem and system levels. There is additional significance associated with this milestone in that first, a formal hand off to manufacturing and coding groups requires that the documentation be complete; second, the allocated requirements baseline comes under Air Force formal change control (any change to the HRS or SRS requires ECP/SCN action through the Air Force Configurational Control Board); and third, the Air Force (user and acquiring agency) concur with the contractor that the proposed design should meet the established requirements.

Recall that at the HSR/SSR milestone the HRSs and SRSs come under contractor formal control. This forces the contractor's configuration management system to track all changes to this baseline. Thus, there is strong incentive for the HRSs and SRSs to be as accurate and complete as possible. While this may seem like a burden it does provide the contractor with the flexibility to change allocated requirements without obtaining Air Force approval. However, at the CDR the Air Force takes control of the HRSs and SRSs using formal configuration change control procedures. This is reasonable since the design is complete at CDR but the contractor still has the flexibility to change it as long as the allocated requirements baseline (HRS/SRS) is not affected. Figure 4 illustrates the baseline control process. This process is a reasonable compromise between flexibility for the contractor and control for the Air Force. This is also significant because approval of the HRSs/SRSs establishes agreement with the contractor on what constitutes a qualified CI since test requirements and test cases are included in the HRSs and SRSs. In summary, the Air Force and contractor have agreed on the detailed requirements (performance, functional, test) for the system, which are traceable to and expanded from the initial system specification. Thus, the interpretation of top level requirements have been accomplished prior to the onset of the test period.

Test Readiness Review

The purpose of the Test Readiness Review (TRR) is to determine whether formal testing of each CI should commence[3]. The specific test requirements were identified in the HRS/SRS and test procedures should be available that meet these requirements. Test results from lower level tests should also be available (software components, hardware assemblies, etc). Appropriate documentation to be used in CI tests should be available as well as the incorporation of changes to design documentation. TRRs should also be held at subsystem and system levels. Because of the approach to controlling baselines, previous agreements on interpretations of top level specifications requirements and the establishment of detailed test criteria, the integration and testing phase should be smoother than in many past programs. Recall that the allocated baseline, initially

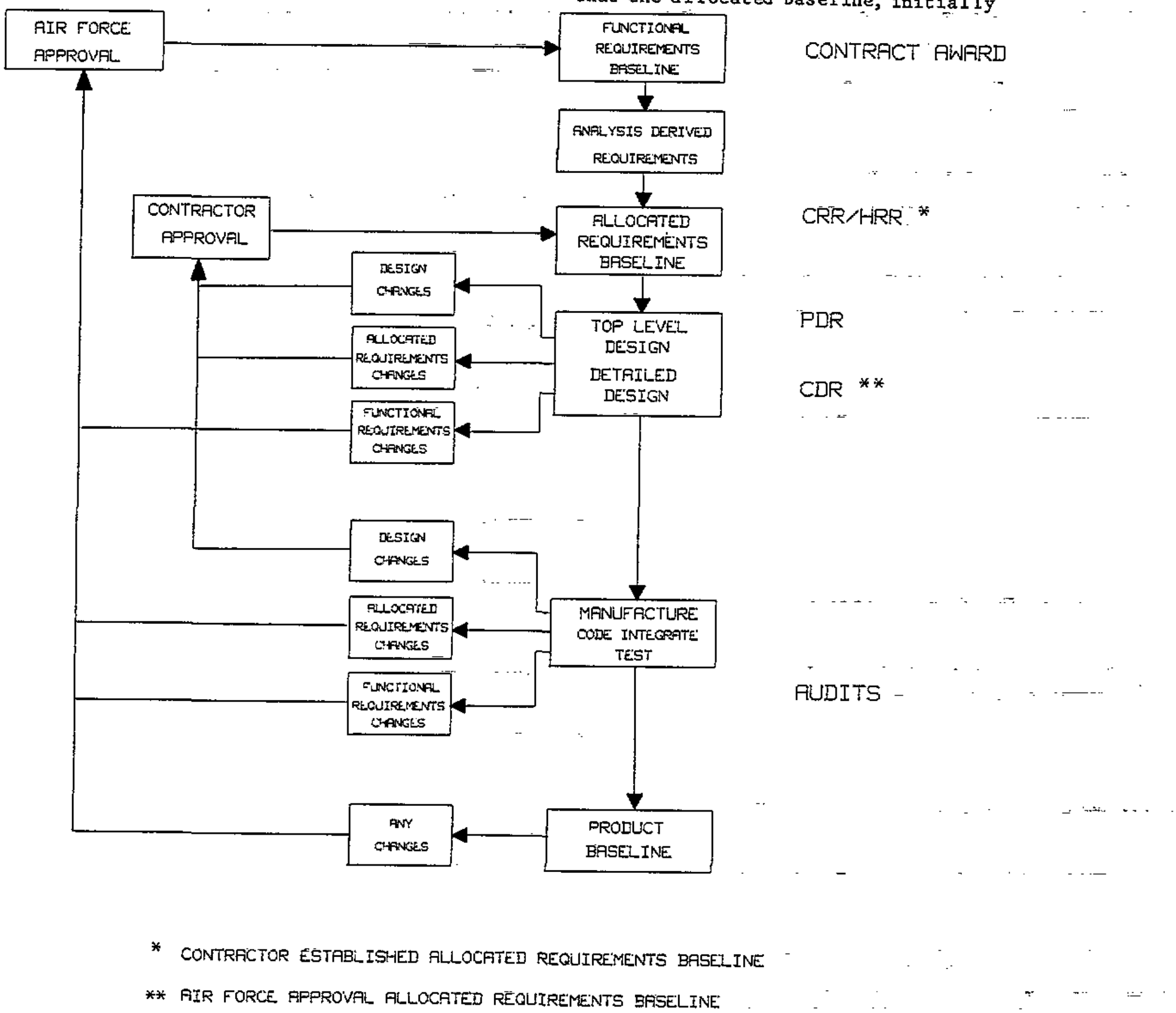

FIGURE 4 BASELINE CHANGES

approved by the Air Force at the CDR, includes test requirements and test cases. This means that for each hardware and software CI as well as each subsystem, the type of verification required is identified in the test matrix, the level that formal verification is performed is identified (system, subsystem, CI, component, subassembly, etc) and detailed test requirements are identified as appropriate. All this represents a considerable expansion of the original functional baseline. The test plan should correlate with these test requirements and the test procedures written for the appropriate level of testing.

It must be recognized that the contractor is responsible for the conduct of all tests. This may not seem like a change from the past but the intent is not to have the Air Force repeat lower level testing, as identified in the allocated baseline, that has been successfully completed and documented by the contractor. The Air Force may selectively witness some of the lower level tests and must review all test results at the appropriate TRR. This approach generally applies to subsystem and lower levels. The Air Force, however, does reserve the right to repeat lower level tests based on the results presented at the TRR or if anomalies are discovered during higher level testing. The amount of the repeat test can be controlled by establishing a baseline time period for Air Force qualification tests in the SOW. This makes it possible for everyone to reasonably plan support of the formal test period. Retesting of discrepancy correction should be in addition to this time period. A fixed period of time should also be established to "tweek" the system to make it look and feel right. No matter how structured the design process is, there will always be the need for some interpretation and subsequent minor adjustment. This approach also reduces the Air Force time in the contractor plant to conduct tests, should reduce the amount of Air Force retesting and gives the contractor more responsibility and authority in the performance of actual tests. The success of this approach requires that both the Air Force and contractor adhere to the process established and use the controls available to check progress and implement corrective action.

Audits

The Functional Configuration Audit (FCA), Physical Configuration Audit (PCA) and Formal Qualification Review (FQR) should be incorporated into the final phases of the development program. These audits are not discussed any further since they are not central issues to the major theme of this paper. However, they should be tailored to meet the individual needs of the program and should be included in the appropriate planning documentation.

PROGRAM IMPACTS

It can be argued that this process is overly burdensome and will extend delivery schedules because of the schedule extension early in the program. I maintain that the strict adherence to this process is not overly burdensome since these requirements have always been present to some degree, but not strictly enforced, that strict enforcement can help, not hinder the utility of the system when it is delivered and that the side benefits will directly contribute to the long term life cycle management benefit, e.g., improved documentation, clearly established baselines and test requirements. Taking the time to establish all the design requirements before beginning the design process in earnest will result in a shorter overall design time period and a shorter integration time period. This is possible since few design changes due to requirements interpretations and incomplete interface definition will occur. With this structured process the potential for achieving concurrency is improved in the long run since the normal development process is already in place to deal with changes. There should also be less down time subsequent to delivery to correct deficiencies.

The type of contract can affect the ease with which this systems management approach is accepted and implemented. It appears that the requirement to conduct complete functional analyses is open ended. It is bounded, although the degree to which it is bounded is dependent on the specificity of the contract specification which is dependent on the completeness of the supporting FEA process. The degree which the system development process presented in this paper must be tailored for specific programs and contract structures requires a detailed examination which is beyond the scope of this paper. However, the principles stated earlier can be readily applied to either cost plus or fixed price acquisitions.

One thing that is clear is that the request for proposal and subsequent source selection must reflect this philosophy. Specific tasks to conduct the functional analyses must be included in the statement of work as well as the specific control mechanisms the Air Force will use to determine whether the contractor needs any redirection. The statement of work must also scope other tasks related to the systems engineering approach discussed in this paper, e.g., program management, program control logistics support. The contents of the proposal and source selection will also change from most of those conducted in the past. A specific design approach cannot be expected to be described in a proposal if an extensive requirements definition is one of the contract tasks. What can be expected is a rigorous discussion of how the contractor will accomplish the required tasks along with the initial version of the basic management plans, e.g., SEMP, CMP, SDP. The proposal should also include a discussion of the relevant technology to be applied in the training system along with the relevant points to be considered in trade studies. Thus, the scope of the evaluations conducted in the source selection will also change. It can be argued that this approach is too risky since a specific design is not defined until a contractor is selected. This is true, but the contractor is still committed to meet the established top level performance requirements and the evaluation should determine the bidders' abilities to perform the required tasks. The long term benefits must be kept in mind. If a specific design approach is proposed the supporting requirements analyses should be included in the proposal to justify the design. In summary, the request for proposal and source selection will be different but there is still definitive information which will require measurable performance under the contract and provide for a realistic evaluation of proposals.

SUMMARY

In this paper I have described a philosophy for managing training system/training device development which is based on the union of Air Force and contractor expertise. The approach gives more responsibility and flexibility to the contractor to conduct the detailed development program and provides the Air Force with the means to manage the contractor. This results in the Air Force giving up some control early in the program but gaining more control subsequent to CDR. There are several mutual benefits for both the Air Force and contractor since an early agreement is reached in the identification of detailed lower level design requirements, interpretations of aircraft performance data and the establishment of a detailed test baseline. Thus, technical reviews can be more meaningful. This should lead to a smoother test phase since it will be easier to clarify apparent test discrepancies by comparing them to a detailed requirements baseline, the allocated baseline, which has been agreed to. This will lead to rapid disposition of the discrepancies and make it easier to determine what is in or out of scope. All this is possible if the necessary time is invested early in the program to complete the requirements analysis efforts needed to establish the allocated baseline. Even though this extends the time period to reach the PDR milestone the detailed design, integration and test phases should be shorter than in the past. The net effect is no increase in program schedule and potential improvement in the ready for training date. There is also more likely to be more training time available shortly after delivery since there will be fewer discrepancies to correct and the update process will be more orderly due to the structured development process previously established. The requirements traceability function will provide a tool for understanding the source of requirements in the allocated baseline even with the turnover of program personnel. Through the use of this systems management process, all parties will contribute directly to the development of the training system.

REFERENCES

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