SIMULATOR DESIGN CRITERIA: NEW EMPHASIS IN CONCURRENT DEVELOPMENTS

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ABSTRACT

Rather than pages of specific design-to performance descriptions and tolerances, development specifications released at contract award for complex training systems often require the simulation of many aspects of a trainer to be "in accordance with design criteria." The use of this reference enables work to begin on aircrew training devices roughly at the same time as full-scale development of the weapon system being simulated. However, this concurrent approach complicates the determination of the simulation performance required. By properly using a design criteria list, the actual detailed requirements for simulation can be well communicated. This paper explores the use of a design criteria list in a typical weapon system trainer development. Examples of design criteria use and misuse are drawn from on-going simulator programs. The need for weapon system prime contractor involvement, well chosen design criteria freeze dates, and documentation of design assumptions throughout the development cycle is emphasized. Through the process illustrated, the accumulation, distillation, and application of design criteria data is portrayed as the cornerstone of representative simulation of actual weapon system performance. In concurrent weapon system and simulator programs, design criteria may actually be more important than the development specification itself in determining simulation requirements.

INTRODUCTION AND BACKGROUND

To the layman who thinks design criteria is not an important concept to understand in relation to Aircrew Training Devices (ATDs), consider that the phrase "simulated in accordance with design criteria" appears 73 times in the B-1B Weapon System Trainer (WST) Prime Item Development Specification. (7) Add to that example the fact that almost each reference means something significantly different in its application, and some additional attention may be stirred. The equivalent to a standard definition of "design criteria" can be found within a generic flight simulator specification or Mil Prime document in Department of Defense acquisition which states: "Design criteria is the entire body of data which describes all aspects of the aircraft." (3) The Deputy for Simulator's generic Statement of Work amplifies the concept somewhat and states:

> Design criteria is the entire body of data which describes all aspects of actual weapon system design, performance, characteristics, interactions, and configuration of the flight vehicle and all on-board systems; all aspects of the external Jammers, Artillery, Radars, and Missiles (JARMs); and all aspects of the interaction of the flight vehicle with the real-world. Design criteria consists of technical reports, schematics, wiring diagrams, memoranda of telephone conversations and meetings, weapon system ACSNs, TCPs, and ECPs, etc. The design criteria represents and is the definition of the weapon system. The design criteria shall include both the data applicable to design and data applicable to test. (4)

At first, it may appear that design criteria is a catch-all concept used to avoid the need to clearly specify the performance and extent of simulation required in ATDs. However, viewed in a different light, the detailed configuration and operation of new weapon systems are rarely completely defined at the time ATD development specifications are composed. Any attempts at comprehensive performance descriptions based on preliminary data may be entirely inadequate or inappropriate. The difficulty of determining detailed fidelity requirements for development specifications is also increased by the sheer complexity of modern weapon systems. The infusion of state-of-the-art, on-board computers and avionics, along with the debugging and refinement of such systems, has lengthened the weapon system maturation process significantly. Simulation of a weapon system undergoing rapid developmental change is an arduous task, and probably no other factor has contributed more to the historical lag in aircraft/simulator concurrency than the proliferation of embedded computers and software in contemporary aircraft. As an example, Figure 1 shows the growth of software lines of code in recent weapon systems. (2)

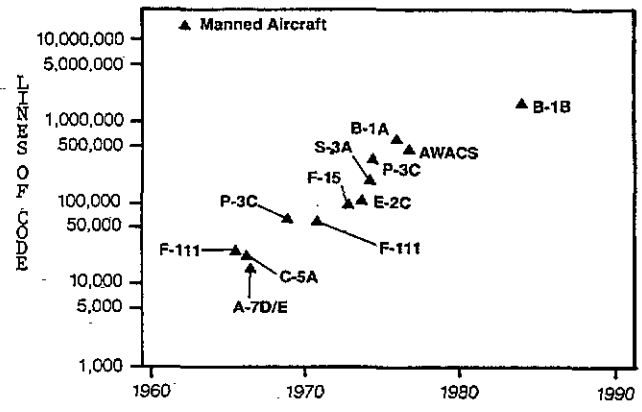

Figure 1 Software Growth in Military Aircraft

The design criteria concept is not a panacea for the challenges of today's simulation tasks, but it has evolved because it is actually the only way work can commence on a simulator virtually at the same time the weapon system is undergoing full-scale development.

In concurrent weapon system/simulator development, considerable contractural effort precedes any detailed simulator design. Even if exacting operational data was available for inclusion in development specifications, it is not necessary at contract award for a complete design-to baseline to be established. The fact that an airplane's flight control system will be modeled is sufficient--the exact stick displacement versus force characteristics are not needed.

Viewed ideally, the specification must pare down the absolute representation of a weapon system into what is functionally required to support the intended training objectives. Then, design criteria will define what is required to be simulated within the given framework. For example, training analysts may determine only five of seven possible radar modes are necessary for simulation in a given training device. However, the specifics of each mode would be a matter left to characteristics defined in the radar design criteria. This surely increases the risk somewhat that the final product may not be representative of the real world system. Yet for reasons cited earlier, this inherent risk is a necessary by-product of concurrent aircraft/simulator developments. It may be advantageous to specify that the radar processing mode time was 2.6 seconds at a 60 nautical mile range, that the range markers were 1/8 inch in diameter, and that the phosphor used in the radar display was P-43. Yet, as previously mentioned, such data frequently is not available, and even if it were, it would be apt to change several times before the aircraft being simulated matured. Finally, with the time alloted for the government and contractor to prepare and approve a specification, it is virtually impossible to define the myriad of such details.

THE DESIGN CRITERIA PROCESS

Perhaps the merits of the concept of design criteria are now established, but how and when is the theory put into practice? Figure 2 outlines the various steps involved in applying the design criteria concept and will be used to illustrate the process in a typical WST development.

Accumulation

First, current practice has been for the government to contractually require that the simulator manufacturer arrange to acquire weapon system design-to data through its own sources. This allows the contractor to receive only the specific data needed for design, forces necessary communication between the simulator and weapon system contractors, and removes from the government the responsibility and potential liability for providing data. However, getting the right data in a timely manner can often be a formidable task. A technical report (ASD-TR-77-25) prepared by Systems Research Laboratories, Inc. determined that in many cases the government is frequently the only organization with sufficient "clout" to perform this function. (6) In most cases, data generated in the course of weapon system development is both first available to and has its dissemination controlled by the government. Additionally, based on the results of a simulator industry survey, the same TR stated that "aircraft manufacturers would not give the same detailed data to simulator manufacturers who were part of a competing aircraft company as they would to those who had no such corporate ties." (6) This situation can potentially hamper an otherwise competent contractor who happens to have actual weapon system development capabilities. All manufacturers surveyed indicated that they preferred to supply such data to the government.

Faced with increasing numbers of developmental programs this approach may prove the only possible avenue. Evidence of the role of government as data supplier is already existent. For instance, on the EF-111A, B-52, and B-1B simulator programs, the procuring agency makes requests to the Foreign Technology Division for classified intelligence data necessary to model JARMs in the electronic warfare environment. The government has also developed a comprehensive data item, entitled "Data Requirements for Simulator Design," which was approved in 1977 following several months of tasking simulator contractors and Department of Defense acquisition organizations to identify a standard format and type of simulator design data. (1)

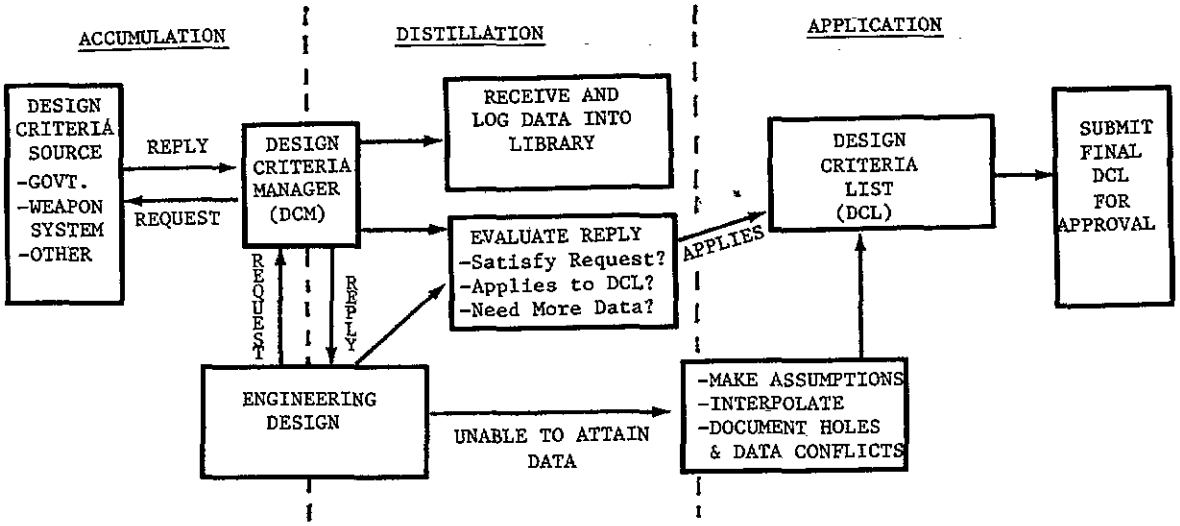

Figure 2 The Design Criteria Process

This data item is frequently placed on the weapon system prime contract to ensure that adequate data is made available for simulator development. It was successfully used during the competitive phase of the B-1B simulator system program to allow both contractors equal access to design criteria prior to commencing their contract efforts.

Regardless of how design criteria is obtained, the design engineers have the responsibility to determine what data is necessary for their efforts and make an appropriate request to the Design Criteria Manager (DCM). This individual must first determine if such data already exists within the company's library. If not, the DCM must in turn make requests to available sources for an answer. It is also the DCM's responsibility to request the most recent applicable data. Empirical information, such as flight test recordings, released drawings, or photos are the preferred sources but often such data may not be available. The concurrent development of the aircraft and simulator systems causes design criteria to be based on the aircraft configuration expected at the time of simulator deployment. Since a large amount of the initial simulator design will occur without the availability of complete flight test and technical order data, it will be necessary to work with predicted aircraft performance and preliminary design data. The procuring agency recognizes that such data must be used. Federal Aviation Administration Advisory Circular 120-40 also admits to the necessity of such an approach and allows predicted data (e.g., wind tunnel or analytical) use in its simulators, provided such data is updated when actual airplane flight test data becomes available. (5)

Distillation

After a reply is provided to the DCM, the data should be logged into the contractor's data library and the distillation process is started. Engineering is again involved in determining whether the data satisfies their original request. This process is also illustrated in Figure 2. Here a formal method of identification and configuration management of design criteria is required. Previous programs such as the B-1B simulator system have used design criteria freeze dates to capture a specific weapon system configuration or performance capability available as of a selected date. However, such data may or may not apply to any given aircraft scheduled for delivery. The safest method is to tie the simulator design criteria to a specific tail number. Physical instrumentation is then easily identifiable, yet embedded software may pose a greater problem. For example, a given aircraft may not contain a block of operational flight software which contains recent changes or a new capability, such as terrain following. Yet, ample design criteria may be available in the form of software documentation, engineering simulations, or design reports to allow simulation of such capabilities in the WST. At this point, it is essential for the procuring agency and contractor, through engineering reviews, to communicate the intent of contract requirements and allow the design criteria process to continue. Without good direction and meticulous reviews, the distillation of large amounts of design criteria will be wasted in inappropriate data gathering activities.

Consequently, in addition to determining whether or not the data provided satisfies their initial request, the DCM and engineering must decide if the data applies to the correct design criteria baseline. If it does, the specific design criteria must be completely identified and controlled. These are the functions of the Design Criteria List (DCL) and it details all the sources of design criteria used in the WST.

The process described above represents a considerable amount of effort and time, yet depicts the process required for a single piece of design criteria. The same process must be performed for all of the required design criteria, and many of the historic delays in detailed design, coding, and hardware/software integration can be attributed to this process being performed late. Because the DCL is essentially a living document, in addition to initial data requests, it must be used to track changes in the weapon system maturation. Far too often, contractors are late in establishing a working DCL, do not request data before it is absolutely necessary, and lose the ability to monitor corresponding weapon system changes. Although design criteria freezes occur traditionally during the CDR timeframe, a simulator contractor should have an essentially complete DCL not later than completion of preliminary design.

Application

While the previous two steps in the design criteria process may be the most difficult, the application phase, again pictured in Figure 2, is probably the most ill-performed. Far too often, a contractor and the government have looked at the DCL as merely another contract data item and have haphazardly listed a slew of aircraft documents, technical orders, and drawings in random order that the engineers have indicated were used in the simulator design. This type of approach removes the ability to ascertain exactly what pieces of data in a given document were actually used in the design. It also reduces the confidence that the previous steps in the design criteria process were carefully performed.

In order for the DCL to be the effective tool it was designed as, it should first be partitioned into categories such as aerodynamics, propulsion, radar, etc., to allow easy determination of where data is used in the simulator design. The simulator contractor must also stress to every person included in the design effort to carefully document all the design criteria used to date -- not just by document number, but by page number, value or logic, document or drawing number, revision and date. Then all the references can be catalogued in the DCL in the following manner: Category: Propulsion, Document TO B-1B-1, Flight Manual, Mar 85, Change 2, Page 2-5, Auxiliary Power Unit (APU) warm-up time, 4.5 secs to 75% RPM. This same design criteria reference should appear in two other places. It should be referenced in the detailed software documentation of the model for the APUs and in the Acceptance Test Procedures as a design standard when testing APU warm-up time. With the current design criteria documentation approach most of this detailed visibility is lost along with the essential design history.

Another area in the application phase which has not been conscientiously performed relates to missing or conflicting data. DI-H-3076, the Data Item Description for the DCL, has provisions for the contractor to document design assumptions, interpolations, and data conflicts. Once a contractor feels they have exhausted all of their design criteria sources, this section of the DCL is intended to be used as a way to communicate trade study results, teleconferences related to detailed system operation queries, and assumptions made throughout the design phase. For example, on the B-1B WST, the contractor has been unable to locate specific data for landing gear and spoiler extension buffet and is relying on data in similar trainers from their experience. This type of information should be placed in the DCL. Additionally, the DCL contains a section to resolve conflicts in data sources. Many times two reliable sources of design criteria may give differing results of an engine fire for example. The DCL should be appropriately annotated to recognize the disparity along with an indication of which source is being modeled. While tiresome to perform, documentation of design conflicts and assumptions illuminates areas where the government can pursue data or if necessary, concur with the assumed design approach and mitigate contractual differences during testing and acceptance.

Concurrency and Changes

Once the DCL has been developed, revised, and submitted for approval at the design criteria freeze, the DCM's job has only begun. Rigid configuration management of the design criteria must be undertaken to incorporate documentation and drawing revisions in order to affect ATD/weapon system concurrency. The DCM must follow weapon system changes via Advance Change Study Notices, Technical Change Packages, Engineering Change Proposals, and internal documentation revisions. It is the DCM's responsibility not only to monitor the receipt of new or revised data, but also to ensure the most current and complete data is provided to the responsible engineers, as well as included in updates to the DCL. By maintaining a close relationship with the weapon system contractor following the completion of detailed design, the simulator contractor can resolve design criteria problem areas, refine predicted data usage, and accomplish timely assessments of simulator impact due to weapon system development. If a comprehensive design criteria list is developed and maintained, the processing of simulator ECPs corresponding to weapon system ECPs is a relatively simple task. All that is required is for the reviewer to determine whether or not a particular weapon system ECP proposes changes to data referenced in the DCL. However, this activity can only take place effectively and efficiently if the design criteria process is performed correctly the first time.

SUMMARY

Notwithstanding the fact that concurrent aircraft and simulator developments are a tremendous challenge, the difficulties can be minimized by placing an increased emphasis on the application of a solid design criteria process. A new approach to this process is necessary because future ATD development specifications will continue to rely on design criteria references to provide the bulk of detailed simulation requirements. Additionally, the using communities' needs for high fidelity ATDs at or before the weapon system initial operational capability will surely increase as the complexity and cost of such systems rise. The government and industry have witnessed a growing inability of simulators to quickly match weapon system performance and configuration amidst developmental change. Only by correcting insufficient past performance in accumulating, distilling, and applying design criteria concepts can this trend be reversed. The design criteria list and its contents require the same attention to detail and contractual concentration as currently provided to development sprecifications.

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5) Federal Aviation Administration Advisory Circular 120-40, "Airplane Simulator and Visual System Evaluation," 31 Jan 83

6) Iffland, Harold L, and Whiteshead, George A., "Aircraft Simulator Data Requirement Study," ASD Technical Report TR-77-25, Jan 77

7) Prime Item Development Specification for B-1B Weapon System Trainer, SSPO-07878-3010, 10 Sep 84

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