COMBINED TEST: A TEAM APPROACH TO ACHIEVING SIMULATOR-AIRCRAFT CONCURRENCY

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ABSTRACT

Can Aircrew Training Device (ATD) testing be restructured to better support concurrent simulator-aircraft development and delivery to the using commands while reducing cost, mitigating schedule risk, and effectively using a reduced number of experienced test personnel? Traditional development and acceptance testing followed an iterative process of identical activities conducted first by the contractor then repeated by the Government. This inefficient process increased program cost and schedule risk. The reality of force downsizing has contributed to test risk by reducing the number of personnel available top support a traditional test program, especially a program seeking to achieve concurrency. To deal with these problems, the B-2 ATD Government-Contractor team developed a combined test methodology to eliminate redundant test, consolidate similar activities and complement the major program objective, concurrent development and delivery of the ATDs. The purpose of this paper is threefold: first, to identify the test related problems associated with concurrent development of complex training devices for a highly software-dependent aircraft not yet in flight test; second, to illustrate the team-oriented structure and process of combined test and how it proved critical to B-2 ATD delivery and functionality; and third, to present the results -- the on-time delivery of two B-2 Aircrew Training Devices that reflect the configuration and capabilities of the first operational B-2 delivered to Air Combat Command.

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THE CONCURRENCY CHALLENGE

From the very beginning, the B-2 Aircrew Training Device (ATD) program faced a major challenge -- to develop and deliver a concurrent ATD prior to deployment of the first operational aircraft. While the parallel procurement of a new weapon system and its associated training system is now an accepted practice, this process was largely untested when the B-2 ATD program began in 1985.

On paper and in a perfect world, parallel development and delivery of both aircraft and training devices is possible. Figure 1 depicts specific paths for each development program that could be taken to achieve concurrency, paths tailored to a program that uses actual aircraft Operational Flight Programs (OFPs) as did the B-2 ATD program. The design and development of the aircraft OFPs parallels the design and development of the supporting ATD hardware, software, instructional features, and environmental factors unique to the simulator are initiated.

Upon simultaneous release of the qualified OFP to flight test and the ATD, the code is tested and integrated into the WST to assure compatibility with ATD interfaces, environmental factors and simulated aircraft functionality. Upon conclusion of flight test, the same basic capability has been integrated, tested in the ATD and accepted by the Air Force. When the aircraft is in the Rework/Update stage, the ATD receives those updates prior to related aircraft flight test and integrates them, with appropriate regression testing, in line with aircraft flight test to assure the same functionality in the ATD as the delivered air vehicle.

In addition to these complex development activities encountered by the B-2 ATD program, the ATD test requirements were greater than those encountered in simulator programs for established aircraft. Not only were we required to test the normal functionality associated with high fidelity flight simulators (i.e., motion, aural cue, visuals, etc.), but we were faced with a brand new radar with very unique capabilities and the most complex OFPs yet fielded for any aircraft. The unique aerodynamic performance of the 'flying wing' also added additional test procedures to assure faithful representation of the aircraft's flight characteristics. All of this had to be accomplished under severe personnel constraints driven by the limited number of aircrew members qualified in the B-2 or even familiar with the B-2 systems.

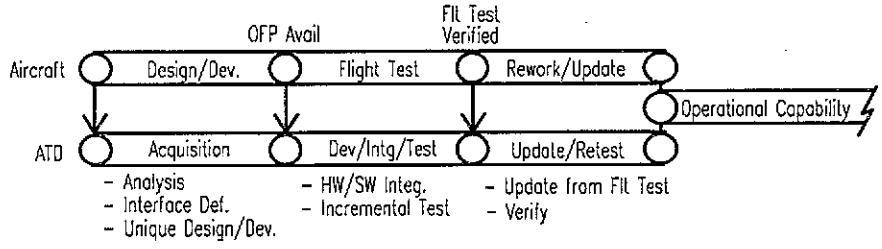

Figure 1
Concurrency

To successfully accomplish a concurrent development is a challenge that requires a relatively stable baseline -- and OFP stability was a challenge as the B-2 aircraft program drove toward initial aircraft delivery. There were three (3) major OFP releases before delivery of the first aircraft, releases involving significant software changes as a result of flight test and the need to accommodate maturing functionality. This incremental delivery of aircraft software was not part of the ATD plan and "broke" our schedule. Each new OFP update required time to integrate into the ATD, and in some cases required redesign of the ATD interface software. All updates required some degree of regression testing activities.

It was obvious that something significant had to be done if we were to incorporate the aircraft changes and still deliver an ATD 90 days prior to the arrival of the first aircraft. The incremental OFP delivery schedule caused our original test and delivery plan, which assumed only one OFP delivery, to be unable to meet program requirements. To deliver and meet the user's needs dictated that time savings be made in the test program and its schedule.

THE PROBLEM - A TRADITIONAL TEST PROGRAM

The original B-2 ATD test program was structured in line with a traditional process required by the Statement of Work (SOW). As illustrated by Figure 2, the test program consisted of a succession of serial and often redundant test activities designed to ensure that the delivered product met the requirements of the system specification as well as the training needs of the user.

The original plan required extensive contractor engineering activities to integrate and verify system performance (including running of the test procedures by the individual engineers). The formal test program then began with Contractor In-Plant Verification Testing, which was the complete accomplishment of the proposed Development Test Procedures (DTPs) by Link Quality Assurance (QA) personnel and witnessed by designated Government quality representatives.

After completion of Verification Testing and correction of all deficiencies identified during this phase, Government Development Test and Evaluation (DT&E) began with a Computer Program System Generation (CPSG). The CPSG or Cold Start was followed by Government In-Plant Development Performance Testing, which was the Air Force accomplishment of selected systems and subsystem tests contained in the DTP. The historical reasons for this form of DT&E are valid, but there is no denying the redundancy of this test activity in light of the previously completed Verification Testing. Once all specification testing was complete (Verification and DT&E), in-plant Initial Operational Test & Evaluation (IOT&E) was planned to evaluate the ATD's operational effectiveness and suitability, as well as to ensure that the first delivered devices met the user's requirements.

The same process of Verification Test, DT&E and IOT&E was repeated on site. Early program schedules included up to 25 weeks of formal in-plant test activity. In addition, the on-site test requirements helped stretch the teardown, pack, install, checkout and acceptance of the ATD to 22 weeks. In all, approximately 11 months from start of in-plant test to final acceptance for each device.

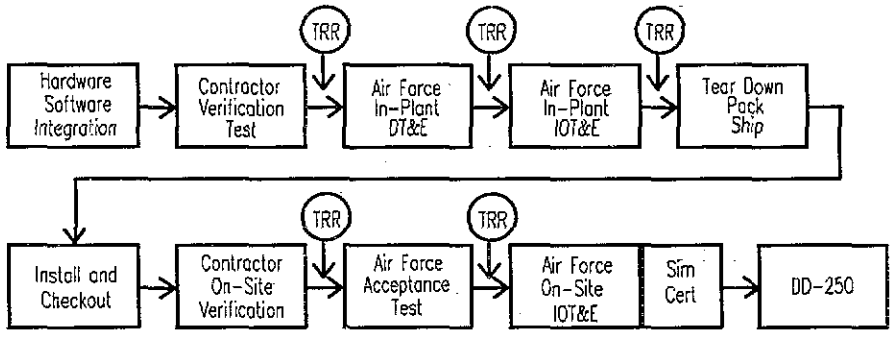

Figure 2
Traditional Test Approach

But time was not the only problem with our original test approach. Each of these serial, and often redundant, test periods was preceded by a readiness review to address a specified set of extensive and often confusing criteria that had to be met in order to continue. Because a different agency was responsible for each phase of the formal test (Contractor QA and "designated government representative" for Verification Testing, SPO Engineering for DT&E and AFOTEC for IOT&E), there were different "agendas" and large variances in methodology for each respective test period. While not a given, the existence of separate tests by separate agencies with separate goals can be extremely inefficient, and not necessarily conducive to success.

As delivery of the first B-2 to Whiteman AFB approached, and the B-2 ATD program moved toward initial training device delivery, it became apparent that the traditional test flow needed a complete overhaul to meet the challenge of an accelerated, dynamic and fiscally constrained program. Test conduct had to be streamlined, test time had to be reduced, all while test quality remained at the highest level. To deliver a quality product under the constraints of the program required a new way of doing business.

THE TEST SOLUTION - TEAMWORK

In late 1991, representatives of the Air Force and CAE-Link met to construct the new test plan and schedule while retaining the goals of a traditional test program through a more efficient approach. All parties recognized the need for innovation and cooperation and put aside individual organizational preferences, requirements and "turf" issues. Discussion ultimately led to a key agreement that all test agencies had equal responsibility for the successful completion of test -- success defined as on-time delivery of a thoroughly tested ATD that met the user's requirements. This led to the formation of a quasi-formal committee charged with all test responsibilities -- the B-2 ATD Joint Test Management Team (JTMT) (See Figure 3). The JTMT was made up of Air Force and Link organizations charged with primary B-2 ATD system test responsibility. Under the JTMT concept:

a. CAE-Link Engineering is responsible for building and integrating the ATD, developing the test procedures, and correcting any deficiencies found during test. Engineering support of actual test conduct is also provided.

b. CAE-Link B-2 ATD Quality Assurance is responsible for accomplishing/witnessing conduct of Verification Testing and any other testing using the DTP.

c. CAE-Link B-2 Program Test Manager is responsible for coordination of all Link formal test activities and providing the Link single point of contact for test.

d. The B-2 System Program Office is responsible for Air Force management of the B-2 ATD Test Program. The SPO Test Manager is responsible for coordination of all Air Force activities and decisions during test.

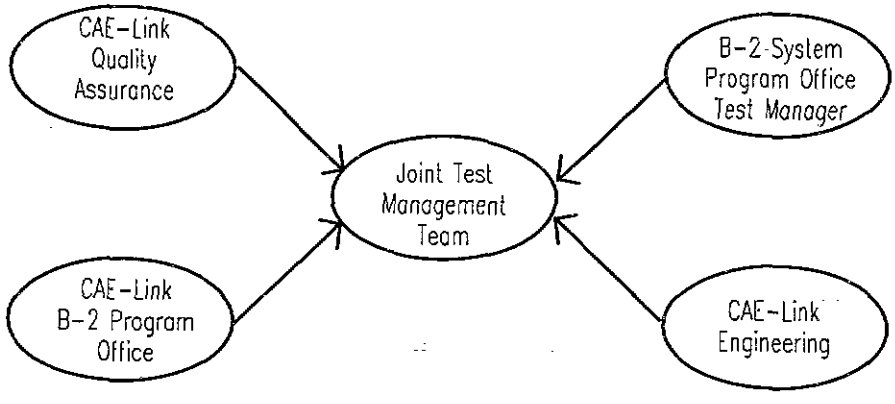

Figure 3
Joint Test Management Team (JTMT)

The members of the JTMT shared equally in decision making and the responsibility for test success. Unanimous decisions were the desired outcome but the Air Force Test Manager, and not other JTMT members, retained "Veto Power". In cases where agreement could not be reached, the Air Force was "most equal". Provisions were made for the Air Force OT&E Test Director to sit as part of the team during periods of IOT&E and to participate, as desired, during other periods of test.

Once formed, the JTMT set to work to restructure the test program, scheduled to begin in just four months. In its efforts, the team drew upon its significant collective experience in simulator development and test *and the experience and work of others in this arena.* One work, the process known as "Simulator Test 2000", developed by an Air Force – Industry Critical Process Team under the auspices of Total Quality Management, played a role in the restructure of efforts. The basic concept of "Simulator Test 2000", with its early assessments, elimination of redundant test activities, and high-level mission activities, was used as we developed the B-2 ATD Combined Test Program depicted in Figure 4.

One of the first requirements for an efficient yet complete test, the Development Test Procedures (DTP), had already been constructed. Written at a relatively high level, they assumed a basic level of system knowledge by the test participants. While this approach resulted in some Test Discrepancies (TDs) due to operator inexperience, the benefits gained in efficiency, as well as a more dynamic and realistic exercising of the system, more than compensated for the few extra TDs. The JTMT next reviewed Link's Configuration Management and Load Build process to reaffirm an earlier Test Planning Working Group decision that a CPSG was unnecessary and need not be accomplished.

The serial and redundant nature of Verification testing and Government DT&E was the next issue we tackled. The solution was straightforward -- combine these two activities. However, the Air Force retained the right to conduct any additional tests it felt were necessary. During Combined Test, the DTP was run jointly by Link QA and designated Air Force representatives and system experts. Any TDs written carried two signatures and subsequent rechecks of these TDs carried two signatures. Side-by-side accomplishment of the DTP *and the hands-on management of test by the JTMT* allowed the B-2 SPO to grant credit for DT&E up front, saving significant time and effort.

Having decided on the process we termed "Combined Test", the JTMT still had to produce a detailed plan to accomplish the full DTP in a more efficient manner while retaining high confidence in the quality of test. This task was even more important since the team wanted to assure that the test was sufficient to preclude exercise of the Air Force's "additional test option". This was accomplished by first grouping the DTP sections into logical blocks and applying historical time factors based on engineering dry runs, and then developing a worst case test sequence. This worst case scenario produced a new serial combined test of 24 weeks duration, one week less than the traditional approach, but too long under our current schedule constraints.

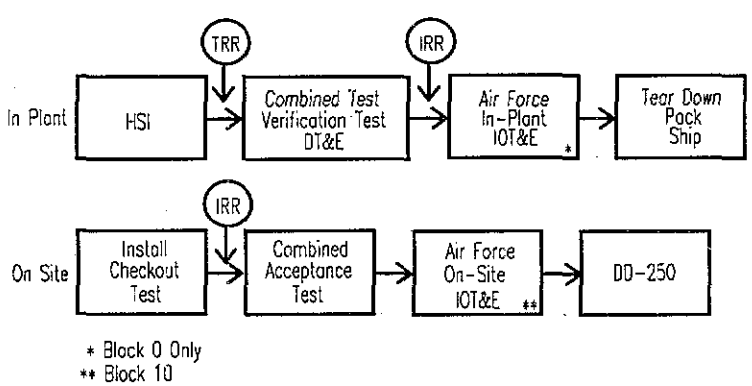

Figure 4
Combined Test Program

Additional "scrubbing" of the test procedures identified specific tests that could be run in parallel or simultaneously (e.g., standalone radar and aero performance tests which do not require use of the ATD). A number of tests that could be run more efficiently during teardown or installation on-site were deferred. Finally, results of engineering dry run times were applied to the remaining tests to provide better run time estimates. The resultant Combined Test period became 13 weeks (an 11 week reduction) for the initial functionality of the B-2 WST, a capability we call Block 0, which represented the first OFP to enter flight test.

Having optimized the development test activities, the more objective DT&E tests, the team then considered the more subjective but equally important Initial Operational Test and Evaluation activities, scheduled to be conducted for two weeks following Combined Test of the Block 0 WST. Considering the different objectives and methodology of IOT&E, the JTMT's goal was to exercise the system in a mission environment as early as possible to identify problems that might not be found while running a specific test procedure but might well be found during IOT&E. This was accomplished by conducting Link Mission Test in conjunction with Combined Test. At least once a week throughout the test period, the aircrew experienced personnel from Link's Operational Training Analysis Group (OTAG) flew a mission scenario approximating flight conditions expected during actual Air Force training. When discrepancies of any kind were identified, they were documented and processed just like any other Test Discrepancy. In addition, comments and observations made during Familiarization Training for the Air Force Test Team were processed as TDs to further identify, track and resolve operational type problems early in the test program. Finally, Air Force aircrews were the designated government representatives during the Integrated System DTP tests, providing additional early operational experience and knowledge. By adding an operational flavor into the test program in its early stages, the test team identified a significant number of operational issues and corrected them before the actual IOT&E, thus saving time and providing a device much more representative of the B-2 at the end of the initial test period. The Air Force conducted IOT&E on the Block 0 WST for seven days and wrote 80 Test Discrepancies, certainly far less than would have been written had this operational flavor not been inserted into the test at an early date.

In all, the B-2 WST Block 0 Combined Test Team accomplished almost 200 separate test procedures plus Initial Operational Test and Evaluation in 16 weeks, a savings of 8 weeks over the original plan and schedule. Running the DTP produced 501 Test Discrepancies and an additional 268 were generated during Link Mission Test, Familiarization Training and IOT&E. This number represents a significant reduction in the number of TDs written in the past on devices of similar complexity.

The B-2 Program's initial experience with Combined Test was not without problems, two of which detracted from the overall success of the effort. The first stemmed from our failure to develop a process/procedure to define the roles and responsibilities of all test participants, particularly the role of the JTMT. This led to protracted discussions involving Test Discrepancy resolution and the conduct of the test, more from a "turf" perspective than a results issue. Prior to the subsequent round of testing, a procedure was written to satisfy all agencies. This procedure allowed each to meet its goals but established the JTMT as the final authority in all test matters.

The second failure was evident by a high rejection rate during TD rechecks, a rate that rose above 25%. We corrected this by adding an additional review of the TD before it was declared Ready for Recheck (RFR), scheduling rechecks in logical blocks of related TDs, and ensuring engineering support during the recheck. By tightening control of the recheck process, the JTMT spent a little extra time up front which saved time at the end and resulted in a Block 10 rejection rate of 6%.

With Block 0 experience and lessons learned, the JTMT turned to the real challenge -- to thoroughly test, both in plant and on site, the first delivered WST and MT. This test was of a new OFP configuration called Block 10, and was done under severe schedule constraints driven by delivery of the first aircraft to Whiteman AFB. The Block 10 configuration was a complete update to the previously tested system, involving new tests as well as regression testing in all functional areas. In addition, the ATD's radar system was being tested for the first time as was the first WST delivered to Whiteman AFB.

Using the same groundrules developed Block 0 test, the JTMT developed a program that tested a limited number of hardware-specific areas prior to and during teardown, and incorporated the remainder into the installation and checkout process. The largest test efforts, the functional aircraft systems, avionics and radar tests were laid out as blocks of related tests in a series of waterfalls that established at which point a function tested in plant would be shipped to site for verification on those devices. Because the on-site devices would be used by Northrop to validate the total training course, our requirement was to have them fully tested in a Block 10 configuration and verified using Air Force crews. Through judicious application of the concepts of combining test, flexible scheduling, juggling of people and plain hard work, our ambitious goals were actually exceeded. DT&E and IOT&E were accomplished on the delivered devices ahead of schedule with significantly fewer TDs than anticipated and the feedback from the using command was extremely positive.

THE RESULTS

It is difficult to compare the earlier B-2 ATD program plan (pre "Block 0") because of different requirements, strategies and processes, as well as different aircraft development plans, that impacted the ATD program. Nevertheless, analyzing the earlier program, we determined that at least 90 weeks were scheduled to test the two delivered devices in plant and on site through two different OFP configurations. By combining test activities, testing off-line where appropriate, assigning procedures to a device and allocation, obtaining early operational input, and constantly working to optimize the test program, the B-2 ATD Test Team was able to deliver two devices ahead of schedule. The total time required for all Block 0 and Block 10 testing, both in plant and on site, was 55 weeks, a reduction in test time of approximately 39%. The nearly nine (9) months saved, permitted the B-2 ATD program to recover and "mend" its schedule that was broken due to aircraft program accelerations and additional OFP deliveries. The dollar savings to the ATD program through the restructure of the test program was initially estimated at $7.5 million.

Saving schedule and money is a significant accomplishment but has no value if the product suffers. The B-2 ATD did not suffer from the efficiencies achieved during Combined Test. Not one test procedure was eliminated -- each procedure was run and every point in the test matrix was accomplished. The overall quality of the product in test was proven by the number and the priority of the Test Discrepancies written and the successful running of the Test Procedures. Almost 11,000 pages of DTP were run during the entire test and 1,235 TDs were written, a ratio of .11 per page, far below the 1.1 or higher experienced on other high-complexity programs. Of these discrepancies, approximately 20% were correctable with a documentation update and not a software or hardware change to the system. During three separate periods of Air Force IOT&E, crewmembers wrote 185 TDs. This number is far below the norm, due in part to the additional 188 TDs identified during Link Mission Test and Familiarization Training. The insertion of an early operational flavor paid big dividends for this program. One final but significant fact is that not one Priority 1 Test Discrepancy that would have stopped test was written during the 55 weeks of formal B-2 ATD testing.

Impressive as these numbers are, the important question is "Did the test support delivery of a concurrent ATD?". The answer is an unqualified Yes. On 20 September 1993, the WST, concurrent with delivered aircraft configuration, was turned over to the 509th Bomb Wing ninety (90) days prior to arrival of the first aircraft. Although only partially tested, this WST had been flown by Air Force crews and determined to be representative of the aircraft. By 17 December, the current Block 10 configuration was completely tested on a WST in-plant and that software sent to Whiteman AFB where it was again determined to replicate the aircraft. In January 1994, the 509th began using the WST and MT with fully tested and concurrent software. By the time the first class of students began to use the delivered WST and MT, a full test of these devices had been completed and both matched the configuration of the operational aircraft.

SUMMARY

Combined Test was a success for the B-2 ATD program for one reason -- teamwork. Each participant was willing to take responsibility for its success or failure. The Joint Test Management Team functioned smoothly in an environment of open communication and trust. In the midst of a tight schedule, problems had to be resolved quickly; time could not be wasted with parochial disagreements. The JTMT attacked problems head on to reach decisions and the Air Force never did use its "veto power". This and other benefits of the Combined Test

approach continue as this is written. An update to the Block 10 aircraft OFPs is being incorporated into the third delivered aircraft. This update is implemented in the in-plant WST and will be tested starting late June 1994. We intend this test to follow the philosophy now standard for the B-2 ATD Combined Test to further streamline test time by reducing on-site test activities to a minimum number of DTPs and relying on Operational Test to verify ATD concurrency with the aircraft.

While Combined Test was a success for the B-2 ATDs, it is also applicable to the vast majority of training system acquisition programs and should provide similar rewards. Program Managers and their Test Directors and the contractors must consider adopting this method of test -- certainly customization for particular programs may be necessary, but the framework presented here provides the basis for implementation. The payoffs are significant and it may mean the difference between a satisfied customer or an improperly prepared student, of a Ready for Training device as opposed to an Available for Training device.