The Human Engineering Division of AAMRL has been involved with strategic bomber human engineering design activities since 1969. Through the accomplishment of research studies and other support activities which have encompassed the offensive, defensive, and flight stations of the B-52 and more recently, the B-1B bomber, AAMRL has provided valuable human engineering design assistance which has supported the evolution of the bombers' avionics suites and enhanced the man-machine interface of the crewstations.

Recently, AAMRL attention has been focused on the development and maturity of the B-1B. Responding to a Strategic Air Command (SAC) request for an interim B-1B simulator for engineering evaluations and crew training, AAMRL produced the B-1B Engineering Research Simulator (ERS). Subsequent experience has proven that the B-1B ERS is both a valuable engineering design assessment device and a reliable primary ground training simulator for B-1B aircrews.

In 1983 AAMRL was approached by representatives of the Strategic Air Command Directorate of Training (HQ SAC/DOTP). The SAC representatives sought to explore the possibility of developing an interim B-1B training simulator to support initial B-1B aircrew training because an initial operational capability for the B-1B Weapon System Trainers was not feasible until after the delivery of operational B-1B aircraft. Although program schedule and funding constraints were severe, AAMRL proposed to rapidly prototype a real-time man-in-the-loop simulator which would be capable of conducting human engineering design evaluation and workload studies, and simultaneously satisfying SAC aircrew training requirements. This simulator development schedule would parallel and be concurrent with the actual B-1B aircraft system development and deployment. A formal Memorandum of Agreement (MOA) was established in 1984 and signed by HQ SAC/DD and AMD/CC (now HSD/CC) to design, develop, test, deploy, operate, and maintain a simulator which eventually was named the B-1B Engineering Research Simulator (ERS).

The requirement for a rapid response to a critical Air Force need dictated an accelerated design approach for B-1B ERS development. Further, establishing a design utilizing both training and research requirements, under severe schedule constraints, required the adoption of and adherence to a proven, structured design methodology. Because a production model of the B-1B aircraft was more than a year from completion, it became necessary to perform a rapid, yet thorough analysis of training, mission, and research requirements. Hardware functionality and software design requirements were established through an iterative process by the joint and coordinated efforts of the principal members of the B-1B ERS development team: AAMRL/HED, HQ SAC/DDTP (Offutt AFB NE), and Science Applications International Corporation (SAIC). SAIC, under contract to AAMRL, served very capably as the systems engineering and integration contractor for the B-1B ERS program.

The B-1B ERS was developed with a “best commercial practice” design philosophy. This philosophy was operationally defined, for this project, as following the intent and spirit of, rather than the literal text of, applicable military specifications. For example, in hardware design and manufacturing, MIL-STD-454 and MIL-STD-1472 were referenced extensively. Applicable...

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sections of these documents were used as design guides, as well as being excerpted and utilized as the basis of manufacturing operating procedures. As another example, software development followed a tailored version of DOD-STD-2167, with most B-1B ERS software products structured and recognizable as being based upon DOD-STD-2167 requirements, although being somewhat less formal in terms of documentation than standard DOD-STD-2167 products. AAMRL believes that the B-1B ERS program benefited from this less formal development approach in terms of reduced staff requirements, reduced development time, and an ultimately lower cost. The logic of this development approach is quietly attested to by the B-1B ERS program details and accomplishments. The B-1B ERS was developed within a two-year period and entailed the coordinated efforts of twelve subcontractors and over 150 vendors; the design, development, test, and integration of over 100,000 lines of executable software code; and the integration of literally several million hardware components. During its tenure at Dyess, and subsequently Ellsworth and Grand Forks Air Force Bases, the B-1B ERS has provided over 20,000 hours of functional training, with a greater than 98% availability for training rate, and has supported the initial combat qualification training for over 80 B-1B aircrews.

The B-1B ERS embodies system requirements encompassing a broad spectrum of design objectives, including normal and emergency procedures, and limited safety-of-flight training. The B-1B ERS provides a realistic emulation of the physical appearance and operational characteristics of the B-1B ERS B-1B crew stations and the associated avionics suites throughout all phases of B-1B strategic missions. Each B-1B ERS crew station has been designed to operate either independently or linked together in an integrated mode for realistic mission simulation.

The principal physical components of B-1B ERS include the flight and aft crew station enclosures (which include corresponding instructor stations), a linkage system which provides data transfer capability and electrical power for the crew stations, and a computational system which is comprised of a Perkin-Elmer 3200 Multi-Processor System (MPS) computer in a configuration consisting of one central processing unit and four auxiliary processing units and associated peripheral devices.

The B-1B ERS flight crew station simulator hardware and software were designed to provide a realistic simulation of the entire B-1B mission, from pre-flight to post-flight activities, including engine start, taxi, takeoff, climb, cruise, tanker rendezvous, descend to low level, manual and automatic terrain following flight, weapons delivery, and instrument approach and landing. The flight crew station simulator also facilitates aircraft commander/pilot maneuvering in reaction to aircraft and ground threats, aircraft malfunctions, and emergency procedures. Simulation of the entire B-1B flight envelope has been provided, as well as B-1B aircraft handling qualities and a fully interactive capability with the other crewstations. Principal features of the flight station include fully functional simulated aircraft instruments panels and Vertical Situation Displays; a McFadden hydraulic control loading system; integral panel, flood and advisory lights; a high fidelity, full six-degree-of-freedom airframe model with non-linear aerodynamics; and comprehensive software models which emulate the functional characteristics of the B-1B aircraft's automatic, primary, secondary, and terrain following flight control subsystems; the fuel and center of gravity management subsystems; the engine and throttle control subsystems; the primary, secondary and auxiliary power subsystems; and the hydraulic subsystem (Johnson, et al, 1989).

The offensive station models the functional performance features of the B-1B aircraft navigation and weapon delivery related avionics subsystems, and supports mission training requirements including: system turn-on, loading, and shutdown; inertial and dead reckoning navigation; auto-pilot steering command generation with great circle, turn short/overflight and tanker rendezvous capabilities; weapon delivery capability including launch sequencing or jettisoning for Short Range Attack Missiles (SRAM), gravity weapons, and safe and in range (SAIR) calculations for SRAM; and malfunction and failure diagnosis activities including manual panel work-around procedures. Physical features include complete integral panel, flood and advisory lighting, and fully functional simulated aircraft panels and displays including two Multi-Function Displays (MFD) and a Radar Target Indicator (RTI). The radar system simulation generates realistic, on-line, real time B-1B real-beam ground map radar imagery by extracting information contained within a supporting data base. The radar data base was obtained by off-line processing of Defense Mapping Agency (DMA) Digital Terrain Elevation Data (DTED), Digital Feature Analysis Data (DFAD), and United States Geological Service (USGS) data utilizing several automated data base processing tools developed to sort and merge the digital data. The B-1B ERS has capability of displaying actual or synthetically generated B-1B Synthetic Aperture Radar (SAR) imagery by utilizing pre-recorded images contained within an optical video disk playback unit. Synthetic SAR image effects modeling and generation capabilities are currently in the process of being significantly upgraded (Johnson, et al, 1989).

The defensive station models the functional and performance features of the B-1B defensive avionics subsystems. Defensive station functionality includes system turn-on and shut-down, threat monitoring, dispensing expendables and initiating electronic countermeasures, malfunction diagnosis and manual work-around/panel back-up capabilities. The defensive station software models the characteristics of the ALQ-161 system and the Tail Warning Function of the Defensive Management Subsystem. The threat electronic warfare environment, including interactive effects with on-board systems, is simulated. All of the threats modeled for a typical Electronic Order of Battle were based upon threat intelligence data. The number and distribution of simulated simultaneous
threats are realistically embedded within the context of the missions simulated. Possible defensive system malfunctions and the software links to other crewstations necessary for integrated mode capability are also provided. The threats modified include early warning radars, ground controlled intercept (GCI) radars, height finder (HF) radars, anti-aircraft artillery (AAA) systems, surface-to-air missile (SAM) systems, airborne intercepts (AI), different types of jammers, and other systems. Physical features include complete integral panel, flood and advisory lighting, and fully functional simulated aircraft panels and displays including one MFD and two Electronic Display Units (Johnson, et al, 1989).

The B-1B flight environment is simulated in such a manner that appropriate effects manifest themselves at all crewstations. These effects include simulations of the operational mission environment including: atmospheric conditions, earth topography, and the hostile and friendly Electronic Order of Battle. While the B-1B ERS is capable of simulated worldwide flight, a set of mission-dependent data bases have been designed by the Strategic Air Command to reflect representative training missions within CONUS. The B-1B ERS is currently equipped with a 500,000 square mile set of terrain and feature digital data bases. This, however, does not preclude the rapid conversion of the B-1B ERS for operational mission rehearsal, if required. The simulated threat data base has been designed and logically integrated into the mission with consideration given to threat type and location. Data bases for the various subsystems (e.g., radar and threat) are correlated with one another. The data base structure was designed to readily allow data base updates and modifications.

In addition to service as the primary ground-based training device for the initial cadre of B-1B aircrews, the B-1B ERS has proven valuable and been used extensively to support human engineering evaluations of B-1B controls and displays. AAMRL utilized the B-1B ERS, while deployed at Dyess AB, to perform an engineering demonstration/effective- ness evaluation of the current B-1B Vertical Situation Display (VSD) Instrument Landing System (ILS) display format and alternatives proposed by the 81st Systems Program Office (SPO) and the B-1B Combined Test Force (CTF)/6510th Test Wing/7610ED, Edwards AB, CA. The goal was to improve current VSD ILS symbology by providing a calibrated aircraft position relative to ILS signals. After performing the evaluation, AAMRL made several recommendations to the B-1B SPO including specific implementation instructions for changing the VSD ILS display (Purvis, et al, 1988). According to B-1B SPO estimates, the study was performed within half the time and for approximately half the cost quoted by major B-1B airframe contractors.

Additionally, the B-1B ERS was utilized in a two-phased study which sought to determine the minimally acceptable resolution requirements or standards for the production of the digital terrain and feature data necessary for simulation of Synthetic Aperture Radar (SAR) systems (Kalinyak and Crane, 1987). Such an attempt to specify minimally acceptable requirements or standards would be a logical attempt to reduce simulator development schedules and costs. The study was sponsored by the Aeronautical Systems Division Training Systems Program Office (ASD/TW), and was a multi-agency activity. Principal participants included: ASD/TW, Air Force Human Resources Laboratory, Operational Training Division (APRL/OT), HQ SAC/DOTP, 96th BW, 28th BMW, 319th BW, AAMRL/RED, SAIC, Universal Energy Systems, Inc., Westinghouse Corp., IFY Corp., and General Electric Corporation. The study was designed to permit a comparison and evaluation of relative task performance utilizing real SAR imagery and several different versions of synthetically generated imagery. The synthetic imagery included three different levels of Digital Feature Analysis Data (DFAD), reflecting various data densities and alternative data generation methodologies, and was compared to actual B-1B SAR system imagery recorded on the BAC 1-11 test aircraft. The study was performed on-site in the B-1B ERS with operational crews from the 96th BW (Dyess ABP), 28th BW (Billowth ABP), and 319th BW (Grand Forks ABP).

Recently, the B-1B SPO requested that AAMRL investigate a specific feature of the B-1B Offensive Radar System Avionics Flight Software (AFS) Block 4.5, known as Automatic Map Outflying (AMO), in an attempt to determine the efficacy of this capability in terms of reducing the Offensive System Officer's workload when compared to pre-Block 4.5 AFS, and the generation of possible recommendations for improvements of AMO, which would subsequently become a portion of the software requirements definition for AFS Block 6.0.

The AMC evaluation has necessarily entailed the update of the B-1B ERS software to the B-1B AFS Block 4.5 configuration; funding for this effort has been provided by the B-1B SPO. Funding for this software update was not available from HQ SAC/DOTP due to extremely severe constraints on SAC operations and maintenance funds. The software update for the AMC study will have the additional benefit of enhancing bomber crew training. Training operations will indirectly subsidize the cost of data collection in the field by funding simulator operations and maintenance and reducing crew travel expenses. This synergy between training and engineering funds has been a unique accomplishment of the B-1B ERS program.

In summary, the previous discussion perhaps illustrates the concept that engineering simulators such as B-1B ERS can provide a timely and cost effective method of prototyping and evaluating certain selected changes in controls, displays, and avionics flight software while simultaneously providing up-to-date operational training. Several factors contribute to this environment including: 1) a readily adaptable engineering development simulation device capable of rapid configuration changes, with simulator configuration control vested in an independent program office (which permits the simulator adaptations necessary to perform studies), and 2) an independent third-party government agency capable of performing credible
research, whose research is additionally considered to be unbiased by all of the other parties responsible for system design (including Program Offices, using Commands, and government contractors). AAMRL/HED believes that the continued participation and interaction between the B-1B SPO, SAC, AAMRL, and other government and contractor organizations will result in the incorporation of cost effective, optimized improvements in the B-1B aircraft and associated systems.

BIBLIOGRAPHY


