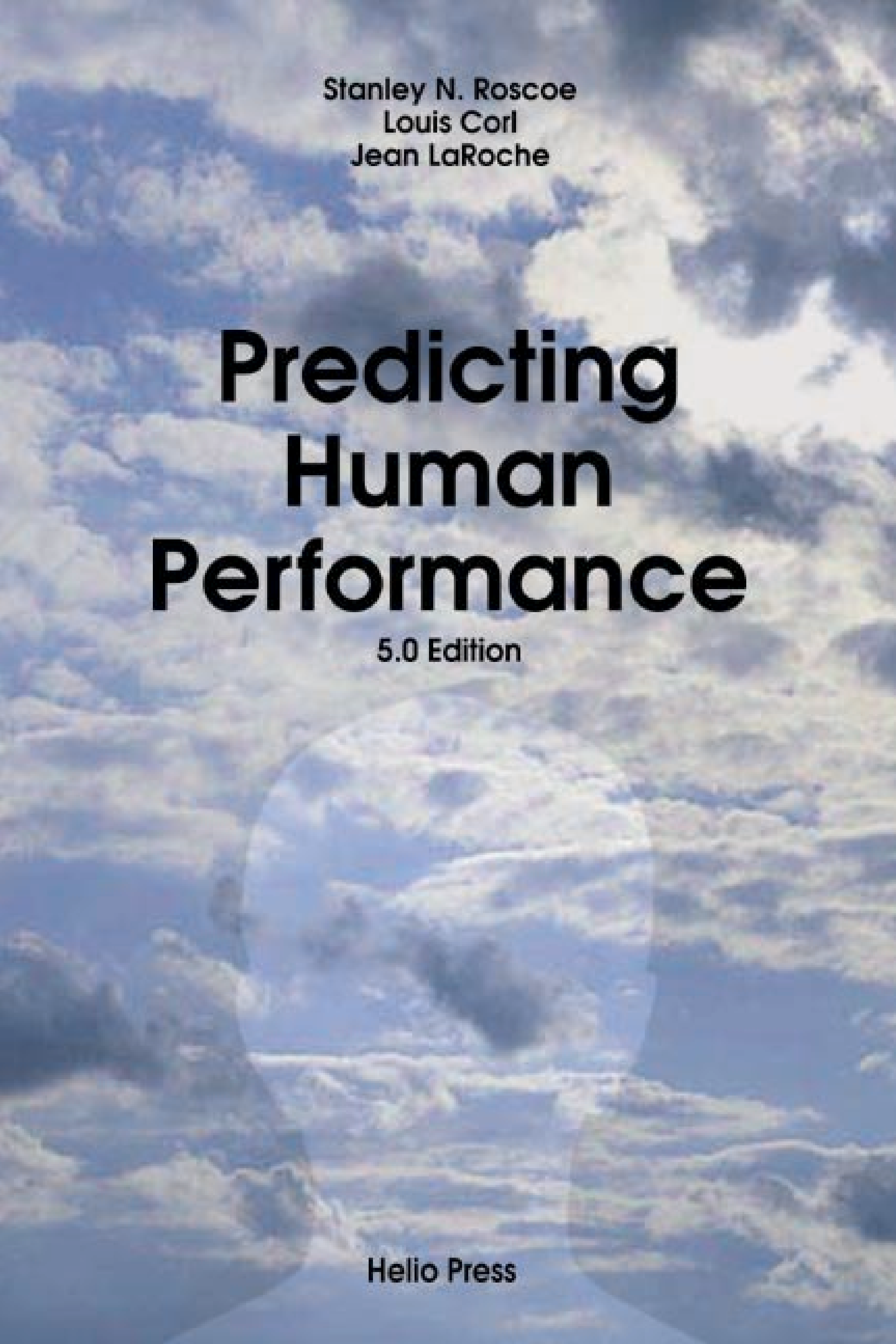

Stanley N. Roscoe
Louis Corl
Jean LaRoche

Predicting Human Performance

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Foreword

The world has many highly effective complex-system operators. Beyond basic intelligence and motor skills, operator performance depends largely on **situational awareness**, the overarching ability to:

- attend to multiple information sources,
- evaluate alternatives,
- establish priorities,
- estimate probable outcomes for different courses of action,
- work on whatever has the highest momentary urgency, without losing sight of the routine,
- reorder priorities as situations deteriorate or improve,
- act decisively in the face of indecision by others.

The solo WOMBAT-CS™ test is designed to measure **situational awareness**, **stress tolerance** and the **attention management abilities** of individual complex-system operators.

When two or more operators are working in teams (or crews), their interactions add a social dimension to individual performance that is now addressed by training in crew resource management (CRM).

The DuoWOMBAT-CS™ addresses the abilities of flight crews and other teams to manage their **collective resources**.

About this book

This book is intended to provide the basic operational information about the WOMBAT-CS Situational Awareness and Stress Tolerance Test. The first five chapters present the historical and scientific backgrounds that led to today's WOMBAT-CS system. The subsequent chapters deal with the technical side of WOMBAT-CS and DuoWOMBAT-CS, from their installation to operation and score interpretation.

1 The Adolescence of Engineering Psychology

This retrospective account of the emergence of engineering psychologists—in the military, in academia, in the aviation industry, in troubleshooting system problems, in consulting, and in course setting for civil and military agencies—is based largely on the recollections of the senior author and many years of correspondence with others of similar vintage or older.

Context

Engineering psychology is the science of human behavior in the operation of systems. Consequently, engineering psychologists are concerned with anything that affects the performance of system operators—whether hardware, software, or liveware. They are involved both in the study and application of principles of ergonomic design of equipment and operating procedures and in the scientific selection and training of operators. The goal of ergonomics is to optimize machine design for human operation, and the goal of selection and training is to produce people who get the best performance possible within machine design limitations.

Principles of Design

Engineering psychologists are concerned first with the distribution of system functions among people and machines. System functions are identified through the analysis of system operations.

Engineering psychologists typically work backward from the goal or desired output of the system to determine the conditions that must be satisfied if the goal is to be achieved. Next they predict—on the basis of relevant, validated theory or actual experimentation with simulated systems—whether the functions associated with each subgoal can be satisfied more reliably and economically with automation or human participation.

Usually it turns out that the functions assigned to people are best performed with machine assistance in the form of sensing, processing, and displaying information and reducing the order of control. Not only should automation unburden operators of routine calculation and intimate control, but also it should protect them against rash decisions and blunders. The disturbing notion that machines should monitor people, rather than the converse, is based on the common observation that people are poor watchkeepers and, in addition, tend to be forgetful. This once radical notion is now a cornerstone of modern system design.

Selection and Training

The selection and training of system operators enhance performance within the limits inherent in the design of the system. Traditional operator selection criteria have tended to emphasize general intelligence and various basic abilities believed to contribute to good psychomotor performance. Although individuals without reasonable intelligence and skill do not make effective operators, it has become evident that these abilities are not sufficient. To handle emergencies while maintaining routine operations calls for breadth and rapid selectivity of attention and flexibility in reordering priorities.

The more obstinate a system is to operate and the poorer the operator-selection criteria, the greater the burden on training. Modern training technology is dominated by computer-based teaching programs, part-task training devices, and full-mission simulators. Engineering psychologists pioneered the measurement of the transfer of training in synthetic devices to pilot performance in airplanes starting in the late 1940s and demonstrated the effectiveness of these relatively crude machines. More importantly, some general principles were discovered that can guide the design of training programs for systems other than airplanes.

Application

Fortunately, improved human performance in system operations can come from all directions. Ergonomic design can make the greatest and most abrupt differences in performance, but improvements in selection and training can be made more readily by operational management. More immediate, though usually less dramatic, improvements in system effectiveness can be made through the redesign of the operational procedures used with existing systems. A brief history of how all this got started during and immediately following World War II is best told by focusing on the pioneers who made it happen.

The Trail Blazers

Among the earliest experimental studies of the human factors in equipment design were those made during World War II at the Applied Psychology Unit of Cambridge University, England, under the leadership of Sir Frederick Bartlett. In 1939 this group began work on problems in the design of aviation and armored-force equipment (Bartlett, 1943; Craik, 1940). Prominent among the early contributors to engineering psychology at APU were Norman Mackworth, K. J. W. Craik, Margaret Vince, and W. E. Hick. Mackworth explored problems of human vigilance. Craik, Vince, and Hick performed classic studies on the effects of system design variables on manual control performance (e.g., Craik, 1944; Craik & Vince, 1943, 1944; Hick, 1945) and on direction-of-motion relationships between controls and displays (Vince, 1945).

Also in 1939, in the United States of America, the National Research Council Committee on Aviation Psychology was established. This committee, first chaired by Jack Jenkins of the University of Maryland and later by Morris Viteles of the University of Pennsylvania, stimulated a wide range of research in aviation psychology primarily at universities. With support from the NRC, Alexander C. Williams, Jr., working with Jenkins at the University of Maryland, began flight research in 1939 on psychophysiological "tension" as a determinant of performance in flight training. These experiments, involving the first airborne polygraph, also appear to have been the first in which pilot performance was measured and correlated with physiological responses in flight. The report of this research was completed in 1941 but was not released until after the war (Williams, Macmillan, & Jenkins, 1946).

In 1940 John Flanagan was recruited to set up a large aviation psychology program for the US Army. Several dozen leading psychologists were commissioned, starting with Arthur Melton, Frank Geldard, and Paul Horst (Koonce, 1984). With America's entry into the war, Flanagan's original organization, the Applied Psychology Panel of the National Defense Research Committee (NDRC), was greatly expanded and its work was extended into what was later to be known as the US Army Air Forces Aviation Psychology Program (Flanagan, 1947).

The history of the NDRC Applied Psychology Panel was recorded by Charles W. Bray (1948), who served as its chief, succeeding Walter S. Hunter. One of the projects started in 1942 was a study of Army antiaircraft artillery at Tufts College, directed by Leonard Mead and William Biel, which led to the development of a gun-director tracking simulator (Parsons, 1972). Early efforts in the United States to study manual control problems systematically were stimulated by the experiments of Harry Helson and W. H. Howe (1943) on the effects of friction and inertia in controls.

Human Engineering

While most of the psychologists in the British Royal Air Force and the United States Army and Navy were involved hands-on in aviator selection and training, others were occasionally called on to deal directly with the subtle problems aviators were having in operating their newly developed machines. During the war the term "pilot error" started appearing with increasing frequency in training and combat accident reports. It is a reasonably safe guess that the first time anyone intentionally or unknowingly applied a psychological principle to solve a design problem in airplanes occurred during the war, and it is possible that the frequent wheels-up-after-landing mishap in certain airplanes was the first such case (Roscoe, 1992).

It happened this way. In 1943 Lt. Alphonse Chapanis was called on to figure out why pilots and copilots of P–47s, B–17s, and B–25s frequently retracted the wheels instead of the flaps after landing. Chapanis, who was the only psychologist at Wright Field until the end of the war, was not familiar with the ongoing studies of human factors in equipment design. Still, he immediately noticed that the side-by-side wheel and flap controls—in most cases identical toggle switches or nearly identical levers—could easily be confused. He also noted that the corresponding controls on the C–47 were not adjacent and their methods of actuation were quite different; hence C–47 copilots never pulled up the wheels after landing.

Chapanis realized that the so-called pilot errors were really cockpit design errors and that by coding the shapes and modes-of-operation of controls the problem could be solved. As an immediate wartime fix, a small, rubber-tired wheel was attached to the end of the wheel control and a small wedge-shaped end was attached to the flap control on several types of airplanes, and the pilots and copilots of the modified planes stopped retracting their wheels after landing. When the war was over, these mnemonically shape-coded wheel and flap controls were standardized worldwide, as were the tactually discriminable heads of the power control levers found in conventional airplanes today.

Psychoacoustics

In the human engineering area of psychoacoustics, the intelligibility of speech transmitted over the noisy aircraft interphones of World War II presented serious problems for pilots and their crews. At Harvard University's Psycho-Acoustic Laboratory, S. S. Stevens, J. C. R. Licklider, and Karl D. Kryter, with help by a young George A. Miller, later the 77th president of the American Psychological Association, conducted a series of articulation tests of standard and modified interphones at altitudes of 5,000 and 35,000 feet in a B-17 bomber (Licklider & Kryter, 1944). Intelligibility was improved by peak clipping the powerful vowel sounds in human speech and then amplifying the remaining balanced mixture of vowels and consonants (Licklider & Miller, 1951). Incidentally, the psychologists also showed that the B–17 could operate effectively at 35,000 feet, which the Air Force had not yet fully realized.

Enter the Engineering Psychologists

In the Military

None of the wartime "human engineers" had received formal training in engineering psychology; indeed, the term hadn't even been coined. Those who became involved in the study of human factors in equipment design and its application came from various branches of psychology and engineering and simply invented the budding science on the job. B. F. Skinner stretched the concept a bit by applying his expertise in animal learning to the design of an air-to-sea guidance system that employed three kamikaze pigeons who learned to recognize enemy ships and voted on which way to steer the bomb they were riding (Skinner, 1960). It worked fine (and still would), but there were moral objections.

After the war, the field of engineering psychology quickly gained momentum. The Applied Psychology Unit in Cambridge, England, was expanded under the leadership of Donald Broadbent, who succeeded Sir Frederick Bartlett as Director. Christopher Poulton's comprehensive work at APU on the dynamics of manual control (integrated in his 1974 book) stands as a major contribution, as does his work in other areas. The psychologists of the Royal Aircraft Establishment at Farnborough conducted a wide range of research under the direction of Air Marshal William Stewart, with John Rolf leading the flight simulation work. Alan Burrows, who learned his trade under Stewart, later headed a human factors unit at Douglas Aircraft in Long Beach, California.

In the summer of 1945, the US Army Air Forces (AAF) Aviation Psychology Program included Colonels John Flanagan, Frank Geldard, J. P. Guilford, and Arthur W. Melton (Flanagan, 1947). By this time the program's personnel had grown to about 200 officers, 750 enlisted men, and 500 civilians (Alluisi, 1994). Their wartime work was documented in 1947 in a series of 19 publications that came to be known as the "blue books." Volume 19, edited by Paul Fitts (1947) and titled *Psychological Research on Equipment Design*, was the first major publication on human factors engineering, or simply "human engineering" as it was referred to in those times.

In August of 1945, with the war about to end, the AAF Aero Medical Laboratory at Wright Field near Dayton, Ohio, established a Psychology Branch. The group, under Lt. Col. Paul Fitts, included 21 officers, 25 enlisted men, and 10 civilians that first year (Fitts, 1947). Prominent psychologists included Majors Judson S. Brown, Launor F. Carter, Albert P. Johnson, and Walter F. Grether; Captains Richard E. Jones and H. Richard Van Saun; First Lieutenants Julien Christensen, John Cowles, Robert Gagne, John L. Milton, Melvin J. Warrick, and Wilse B. Webb; and civilian William O. Jenkins. Fitts was succeeded as Technical Director by Grether in 1949.

Meanwhile, Arthur W. Melton and Charles W. Bray were building the Air Force Personnel and Training Research Center, commonly referred to as "Afpatrick," into a huge research organization with laboratories at Mather, Sted, Williams, Tinker, Goodfellow, Lowry, Tyndall, Randolph, and Lackland Air Force Bases. Prominent psychologists included Edward Kemp at Mather, Robert Gagne at Lackland and later at Lowry, Lloyd Humphreys at Lackland, Jack Adams at Tyndall, and Bob French at Randolph. In 1958 this farflung empire was dismantled by the Air Force. Most of the psychologists returned to academia, while others found civilian research positions in other laboratories.

The Navy was not to be outdone by the Air Force. In late 1945, human engineering in the Navy was centered at the Naval Research Laboratory in Washington, DC, under Franklin V. Taylor. The stature of NRL was greatly enhanced by the originality of Henry Birmingham, an engineer, and the writing skills of Taylor, a psychologist. Their remarkable 1954 work, *A Human Engineering Approach to the Design of Man-Operated Continuous Control Systems*, had an unanticipated benefit; to understand it, psychologists had to learn about the electrical engineering concepts Birmingham had transfused into the psychology of manual control.

Another fortunate development in 1945 was the establishment of the Navy's Special Devices Center at Port Washington on Sands Point, Long Island, with Leonard C. Mead heading its Human Engineering Division. SDC invented and developed many ingenious training devices on site and monitored a vigorous university program for the Office of Naval Research, including the original contract with the University of Illinois Aviation Psychology Laboratory. Task

Order XVI, as it was known, was renewed for 20 consecutive years. Mead went on to head an engineering psychology program at Tufts College and from there to the upper management of the college and eventually of the Smithsonian Institution.

Project Cadillac, the first complex manned-system simulation study was conducted at the Sands Point facility from 1948 until 1955, with experiments actually getting underway in 1951 (Parsons, 1972). The project, initially directed by New York University, grew out of the Navy's early problems with airborne combat information centers (CICs) designed to perform surveillance functions and later interception control. Robert Chapman, Vince Sharkey, and James Regan were prominent contributors. H. M. "Mac" Parsons cut his human engineering teeth on Project Cadillac in 1950 while still a graduate student at Columbia University. He stayed with the project when the NYU Electronic Research Laboratories split off as the Riverside Research Institute in 1952.

In 1946, a Human Engineering Division was formed at the Naval Electronics Laboratory in San Diego under Arnold Small, whose first criterion for hiring, it seemed, was that an applicant could play the violin in the San Diego Symphony. Small, who had majored in music and psychoacoustics and played in the symphony himself, hired several musicians at NEL, including Max Lund, who later moved on to the Office of Naval Research in Washington, and Wesley Woodson, who published his *Human Engineering Guide for Equipment Designers* in 1954. Outstanding contributions were also made by John Stroud (1955), known for his "psychological moment" concept, and Carroll White (1956), who discovered and validated the phenomenal effect of "visual time compression" on noisy radar and sonar displays.

Similar to the pattern after the First World War, some psychologists remained in uniform, but more, including Grether, Melton, Bray, Kemp, Gagne, Humphreys, Adams, French, Taylor, Mead, and Small, stayed on as civil servants for varying tenures, as did Julien Christensen and Melvin Warrick, who had long careers at the Aero Medical Laboratory at Wright Field. Colonel Paul Fitts wore his uniform until 1949, then joined academia and opened his Laboratory of Aviation Psychology at Ohio State University. Many who had not completed their doctorates went back to graduate school on the GI Bill. A few who had earned Ph.D.s before the war joined universities where they could apply their wartime experiences to the training of a new breed of psychologists.

In Academia

On January 1, 1946, Alexander Williams, who had served both as a selection and training psychologist and as a naval aviator, opened his Aviation Psychology Laboratory at the University of Illinois (Roscoe, 1994). The laboratory initially focused on the conceptual foundations for mission analysis and the experimental study of flight display and control design principles (Williams, 1947, 1980). Soon a second major thrust was the pioneering measurement of transfer of pilot training from simulators to airplanes (Williams & Flexman, 1949; Flexman, Roscoe, Williams, & Williges, 1972). And by 1951 experiments were underway on the world's first air traffic control simulator (Johnson, Williams, & Roscoe, 1951).

Also on January 1, 1946, Alphonse Chapanis, who had served as a psychologist but not as a pilot, joined the Psychology Department of Johns Hopkins University. Initially, Chapanis concentrated on writing rather than building up a large research program with many graduate students, as Williams was doing at Illinois. The result was the first textbook in the field, *Applied Experimental Psychology*, a monumental work for its time and still a useful reference (Chapanis, Garner, & Morgan, 1949). With the book's publication and enthusiastic reception, engineering psychology had come of age, and aviation was to be its primary field of application in the years ahead.

Strong support for university research came from the Department of Defense, particularly from the Office of Naval Research and its Special Devices Center and from the Air Force's Wright Air Development Center and its Personnel and Training Research Center. The Civil Aeronautics Administration provided funds for human engineering research via Morris Viteles and his NRC Committee on Aviation Psychology. In 1950 that committee was composed of Viteles as chairman, N. L. Barr, Dean R. Brimhall, Glen Finch, Eric F. Gardner, Frank A. Geldard, Walter F. Grether, W. E. Kellum, and S. Smith Stevens.

The research sponsored by the CAA via the committee was performed mostly by universities and resulted in a series of studies that became known as "the gray cover reports." Number 84, by A. C. Williams, Jr., and S. N. Roscoe (1949), described the first experimental study of instrument displays designed for use with the new VOR/DME radio navigation system. Number 92, by S. N. Roscoe, J. F. Smith, B. E. Johnson, P. E. Dittman, and A. C. Williams, Jr. (1950), reported the first simulator evaluation of a map-type VOR/DME navigation display employing a CRT in the cockpit. Number 122 described the previously mentioned first air traffic control simulator (Johnson, Williams, & Roscoe, 1951).

When Paul Fitts opened his Laboratory of Aviation Psychology at Ohio State in 1949, he attracted a flood of graduate students, many of them veterans, as Alex Williams had been doing since 1946 at Illinois. Charles W. Simon, Oscar Adams, and Bryce Hartman started the flow of Fitts doctorates in 1952. Simon joined the Rand Corporation in Santa Monica and Adams the Lockheed-Georgia Company in Marietta. Hartman embarked on his long career at the Air Force School of Aviation Medicine in San Antonio. By that time the air traffic control studies for Wright Air Development Center were under way, and Conrad Kraft was developing his "broad band blue" lighting system for radar air traffic control centers (Kraft & Fitts, 1954).

Williams stayed at Illinois until 1955 when he joined Hughes Aircraft Company and fashioned a second career, this time as a practicing engineering psychologist (Roscoe, 1980, 1994). He was succeeded at Illinois by Robert C. Houston for two years and then by Jack A. Adams until 1965, when the laboratory was temporarily closed. Fitts remained at Ohio State until 1958 when he rejoined his wartime friend Arthur Melton, who had moved on to the University of Michigan when Afpatrick was being dismantled (Pew, 1994). Fitts was succeeded by another brilliant psychologist, George Briggs (Howell, 1994). Williams, Fitts, and Briggs all died of heart attacks at early ages, Williams and Briggs at 48 and Fitts at 53.

The laboratories of Williams at Illinois, Chapanis at Johns Hopkins, and Fitts at Ohio State were by no means the only ones involved in the engineering psychology field in the 1940s and early '50s, but they were the ones that produced the lion's share of the engineering psychologists during that period. Other universities with outside support for graduate students doing human engineering research in aviation included Harvard, MIT, California at Berkeley, UCLA, Southern California, Tufts, Purdue, Michigan, Columbia, and Maryland. Several prominent engineering psychologists were mentored by Ernest McCormick at Purdue in the late 1950s and early '60s.

In the Aviation Industry

The students of Williams and Fitts invaded the aviation industry in the early 1950s. The boom was on, especially in southwest Los Angeles where one could park along Airport Boulevard at the east end of LAX Runway 25 Left and see new North American and Douglas planes being rolled out and tested every day. Douglas-El Segundo alone had five different production lines running simultaneously in 1952. From a small hill near the airport, one could see the plants of Douglas, North American, Northrop, and Hughes, which were growing to enormous size, and Lockheed was just over the Hollywood Hills in Burbank. Strange planes like the Northrop flying wing flew low over the Fox Hills Golf Course.

Stanley N. Roscoe was Williams' first student at Illinois and received his Ph.D. in 1950 but stayed on at the lab for two years to complete a flight-by-periscope project for the Navy's Special Devices Center (Roscoe, Hasler, & Dougherty, 1952/1966). Then, in 1952, Roscoe was recruited by Hughes Aircraft Company to organize a Cockpit Research Group and went on to become manager of the Display Systems Department. Earlier that year Walter Carel, who had completed all but his dissertation at Columbia University, was hired by General Electric to do research on flight displays, and William B. Knowles joined GE soon thereafter. In 1955 Charles Hopkins and Charles Simon joined Williams and Roscoe at Hughes, and Knowles and Carel soon followed.

Starting in 1953, several of the airplane and aviation electronics companies hired psychologists, but few of these had training in engineering psychology, and fewer yet had specialized in aviation. As the graduates of the universities with aviation programs started to appear, they were snapped up by industry and by military laboratories as it became painfully apparent that not all psychologists were alike. In a few cases groups bearing such identities as cockpit research, human factors, or human factors engineering were established. In other cases the new hires were assigned to the "Interiors Group," traditionally responsible for cockpit layouts, seating, galleys, carpeting, and rest rooms.

In this environment, Neil Warren in the Psychology Department at the University of Southern California and John Lyman in the Engineering Department at UCLA introduced advanced degree programs for many who would distinguish themselves in the aerospace field. Starting in the late 1940s, Warren had used the human centrifuge on the University of Southern California campus (at that time the only one on the west coast) to do display research. It was in Warren's facility where it was first demonstrated that a single "drag" on a cigarette would measurably reduce the number of *G*'s a pilot could withstand before "graying out" in the centrifuge.

Harry Wolbers, a 1955 Warren graduate, was the first engineering psychologist hired by the Douglas Aircraft Company. Wolbers was the human factors leader for Douglas in their prime contract for the Army-Navy Instrumentation Program (ANIP). Another Warren product was Glenn Bryan, who became the first director of the Electronics Personnel Research Group at the University of Southern California in 1952 and went on to head the Psychological Sciences Program at the Office of Naval Research for more than 20 years. Gerald Slocum, who joined Hughes Aircraft in 1953 and later earned his master's degree with Lyman at UCLA, would rise to be a Vice President of the company and eventually of General Motors.

In the east, Jerome Elkind, a student of J. C. R. Licklider at MIT, formed the original human factors engineering group at RCA in the late 1950s. Lennert Nordstrom, a student of Ross McFarland (Ritchie, 1994) at Harvard, organized the human factors program at SAAB in Sweden in the late 1950s. Thomas Payne, Douglass Nicklas, Dora Dougherty, Fred Muckler, and Scott Hasler, all students of Alex Williams, brought aviation psychology to The Martin Company in the mid 1950s. And Charles Fenwick, a student of Ernest McCormick at Purdue, became the guru of display design at Collins Radio in the early 1960s. Managers in industry were gradually recognizing that aviation psychology was more than just common sense.

In Troubleshooting System Problems

In the late 1940s and early '50s, an unanticipated technological problem arose in the military community, one that obviously had critical human components. The new and complex electronics in both ground and airborne weapon systems were not being maintained in dependable operating condition. The weapon systems included radar and infrared guided missiles and airplanes with all-weather flight, navigation, target-detection, and weapon-delivery capabilities. These systems had grown so complex that more often than not they were inoperable and, even worse, unfixable by ordinary technicians. Few could get past the first step—"troubleshooting" the failures. It was becoming evident that something had to be done.

The first alert on the scale of the problem came from the Rand Corporation in the "Carhart report" which documented a host of people problems in the care of electronic equipment (Carhart, 1953). The technicians needed better training, aiding by built-in test circuits, simulation facilities for practicing diagnoses, critical information for problem solving, and objective performance evaluation. To address these problems, the Office of Naval Research in 1952 contracted with the University of Southern California to establish an Electronics Personnel Research Group with the mission of focusing on the people aspects of maintaining the new systems coming on line.

The original EPRG, organized by Glenn Bryan, included Nicholas Bond, Joseph Rigney, Laddie LaPorte, William Grings, L. S. Hoffman, and S. A. Summers. The reports published by this group during the 1950s (e.g., Bryan, Bond, LaPorte, & Hoffman, 1956; and Bryan, Rigney, Bond, LaPorte, Hoffman, & McAllister, 1959; and Grings, Rigney, Bond, & Summers, 1953) had a major impact on the subsequent efforts of the military to cope with the problems of maintaining electronic systems of ever increasing complexity. The lessons learned from this early work were later set forth in Nick Bond's 1970 *Human Factors* article, "Some Persistent Myths about Military Electronics System Maintenance," which won the Jerome H. Ely Award of the Human Factors Society.

In Consulting

In parallel with these developments, several small companies were organized to provide research, design, and consulting services to industry and the government. Among the earliest of these were Jack Dunlap's Dunlap and Associates, Bob Sleight's Applied Psychology Corporation, Harry Older's Institute of Human Relations, and John Flanagan's American Institutes for Research (Alluisi, 1994, p.16). Of these, the American Institutes for Research and Dunlap and Associates expanded into fields other than engineering psychology. Still, Dunlap and Associates warrants extra attention here because of its predominant association with engineering over a long period and the nature of its contributions.

In 1946, Captain Jack Dunlap separated from the US Navy, joined The Psychological Corporation in New York City, and immediately established a bio-mechanics division (Orlansky, 1994). Dunlap's initial recruits were Ralph C. Channell, John D. Coakley, Joseph Gallagher, Jesse Orlansky, and Martin A. Tolcott. Of this group, all but Gallagher, an accountant, left "The Psych Corp" in 1947 to form what would become Dunlap and Associates in 1950. In addition to its main offices and laboratories in Stamford, Connecticut (until 1963), the company had a sizeable branch office in Santa Monica headed by Joseph Wulfeck.

In the 1950s, Jesse Orlansky of "D&A" played a key role in the forward-looking Army-Navy Instrumentation Program (ANIP), working closely with Douglas Aircraft, the prime contractor, and with Walter Carel of General Electric, the originator of the "contact analog" concept (Carel, 1960, 1961). Two of the best minds in the D&A organization were those of Jerome H. Ely and Charles R. Kelley, but in quite different ways. A memorial plaque describes Ely, who died at age 39, as a "scholar, scientist, teacher and gentle man" (Tolcott, 1994). Kelley, on the other hand, saw a perfect continuum between science and mysticism, but his seminal research on predictor displays and his book *Manual and Automatic Control* (1968) were highly creative contributions.

In Course Setting

During the 1950s, "blue ribbon" committees were frequently called on to study specific problem areas for both civilian and military governmental agencies, and aviation psychologists were often included on and sometimes headed such committees. Three of the most influential committee reports, each of which contained major contributions by Alex Williams, included:

Human Engineering for an Effective Air-Navigation and Traffic-Control System. (Fitts et al., 1951).

Human Factors in the Operation and Maintenance of All-Weather Interceptor Systems. (Licklider et al., 1953).

The USAF Human Factor Engineering Mission as Related to the Qualitative Superiority of Future Man-Machine Weapon Systems. (Fitts et al., 1957).

The air-navigation and traffic-control study by the Fitts committee was of particular significance because, in addition to its sound content, it was a beautifully constructed piece that set the standard for such study reports. The group Fitts assembled included Alphonse Chapanis, Fred Frick, Wendell Garner, Jack Gebhard, Walter Grether, Richard Henneman, William Kappauf, Edwin Newman, and Alexander Williams.

The study of all-weather interceptor operation and maintenance by J. C. R. "Lick" Licklider et al. (1953), though not as widely known, marked the recognition by the military and the aviation industry that engineering psychologists in the academic community had expertise applicable to equipment problems not available within the military at that time. Licklider's committee included George Clementson, Joe Doughty, Bill Huggins, Charles Seeger, C. C. Smith, Alex Williams, and Jay Wray.

Not all of the reports of this genre were the products of large committees. Others written in academia, usually under military sponsorship, included:

Handbook of Human Engineering Data, generally referred to as "The Tufts Handbook," produced at Tufts College under a program directed by Leonard Mead for the Navy's Special Devices Center and heavily contributed to by Dunlap and Associates (Tufts College & US Naval Training Devices Center, 1949), followed by:

Vision in Military Aviation by Joseph Wulfeck, Alexander Weisz, and Margaret Raben (1958) for the Wright Air Development Center. Both were widely used in the aerospace industry.

Some Considerations in Deciding about the Complexity of Flight Simulators, by Alex Williams and Marvin Adelson (1954) at the University of Illinois for the USAF Personnel and Training Research Center.

A Program of Human Engineering Research on the Design of Aircraft Instrument Displays and Controls, by Alex Williams, Marvin Adelson, and Malcolm Ritchie (1956) at the University of Illinois for the USAF Wright Air Development Center. (Adelson went on to form the first human factors group in the Ground Systems Division of Hughes Aircraft, and Ritchie formed his own research and consulting company in Dayton, Ohio.)

Perhaps the two most influential articles in the field during the 1950s were:

"Engineering Psychology and Equipment Design," a chapter by Paul Fitts (1951) in the *Handbook of Experimental Psychology* edited by S. S. Stevens, the major source of inspiration for graduate students for years to come, and

"The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing Information" in the *Psychological Review* by George A. Miller (1956), which encouraged quantification of cognitive activity and shifted the psychological application of information theory into high gear.

Historical Perspective

Taken as a whole, these key reports and articles—and the earlier research on which they were based—addressed not only pilot selection and training deficiencies and perceptual-motor problems encountered by aviators with poorly designed aircraft instrumentation but also flight operations, aircraft maintenance, and air traffic control. All of these problem areas have subsequently received serious experimental attention by engineering psychologists both in the United States and abroad. There are now some established principles for the design, organization, maintenance, and operation of aviation systems that have application beyond the immediate settings of the individual experiments on which they are based.

The early educators in the field—Alex Williams, Al Chapanis, Paul Fitts, Ross McFarland, Len Mead, Lick Licklider, Neil Warren, John Lyman, Jack Adams, George Briggs, and Ernest McCormick—had in common a recognition of the importance of a multidisciplinary approach to aviation problems, and their students were so trained. The early giants, on whose shoulders we walk, could only be delighted by the extent to which all researchers and practitioners now have access to once unimagined information and technology to support creative designs based on sound behavioral engineering principles.

ACKNOWLEDGMENTS

In preparing this historical review, we have drawn on articles by Earl Alluisi (1994), Paul Fitts (1947), and Jefferson Koonce (1984); on the short biographies of George Briggs, Jack Dunlap, Paul Fitts, Ross McFarland, and Jerome Ely, respectively, by Bill Howell, Jesse Orlansky, Dick Pew, Malcolm Ritchie, and Marty Tolcott in the monograph titled *Division 21 Members Who Made Distinguished Contributions to Engineering Psychology*, edited by Henry Taylor and published in 1994 by Division 21 of the American Psychological Association; and on Mac Parsons' 1972 book *Man-Machine System Experiments*. We also received valuable personal communications about "Afpatrick" from Jack Adams (1995) and about the USC Electronics Personnel Research Group and the strange planes flying low over the Fox Hills Golf Course from Nick Bond (1995).

2 Predicting Human Performance

Background

While the early engineering psychologists were primarily concerned with the human factors in equipment design, many other psychologists were involved in personnel selection and the transfer of training in simulators to the operation of complex systems—mainly airplanes but also some fairly complex weapon systems. The involvement of psychologists in pilot selection had started in the first World War, and during World War II they became deeply involved. The results of the psychomotor and other tests they developed and used were submitted to statistical analysis, and the modest conclusion was that they could account for about 20% of the variance in pass/fail numbers for pilot, navigator, and bombardier trainees.

The Roots of WOMBAT-CS

The Need

For most of this century, psychologists have been developing precise measures of human intelligence and somewhat less precise but nonetheless useful instruments for describing human personality factors. Unfortunately, they have been less successful in assessing human aptitudes for operating nuclear reactors, controlling air and surface traffic, directing civil disaster responses, and providing emergency medical services, to name but a few of the many complex operations humans perform daily. In recent years, with the advent of high-speed computers, the military have invested heavily in the development and validation of selection batteries that now account for more than 25% of the variance in training success but still have no evident correlation with operational performance after training.

The need for valid tests of complex operational aptitude is increasing as the explosion in information technology and associated automation makes more complex operations possible and the cost of placing the wrong person in charge greater than ever. Increasing the information available gives the operator more to attend to, and automation makes it all the more important and difficult to keep track of everything that is going on and decide when some intervention is critical. This is now called **situational awareness**, and this ability is also centrally involved in **crew resource management (CRM)**.

The costs of haphazard personnel selection are not limited to those resulting from bad judgment and mismanagement of critical operations. **It is also costly to invest in the training of individuals who fail to reach criterion performance levels after training or, worse yet, pass all training tests but then are unable to stand up under operational stress**. As so often happens with trainees, the individual may have all of the skills and knowledge normally required but be unable to put them together in the confusion of a complex incident.

The Difficulties

The failure to develop tests of high predictive validity for complex operational aptitude has been caused by several factors, **the first of which is the usual clouding of operational performance criteria against which to validate any such test**. If measures of complex job performance are unreliable, as they typically are, there is no way that the high predictive validity of a test can be shown statistically. The pass-fail criterion would be of value if approximately equal numbers of trainees passed and failed, but when the ratio is four or five to one, as in many training programs, it is almost worthless. Rating scales are no better when almost all trainees are given the same grade.

Aside from the criterion problem, development of effective aptitude tests has been crippled by the notion that performance of complex operations depends on a collection of individually simple abilities. Consistent with this idea, batteries have been developed to test reaction time, manual dexterity, short-term memory, spatial orientation, and the like. The fact that such batteries account for only about 25 percent of the variance in training success is also caused in part by the correlations among the so-called basic abilities measured by the individual tests. **Any one or two of the tests provides almost as much predictive power as the entire battery. Administering the rest of the battery is a waste**.

The Secret

The secret of operational aptitude testing is to recognize the complexity of what we are trying to predict and construct a measuring instrument of similar complexity. The fact that expanding a test battery adds little predictive validity does not mean that a selection test should be short to be cost effective. It is wishful to expect situational awareness and stress tolerance to be revealed reliably in a short test. If a day or even part of two days is required by most candidates to approach a terminal performance level on an aptitude test, its application would still be cost effective if only candidates of high aptitude were selected and the probable failures were rejected before large sums had been invested in their training.

While situational complexity is necessary to test situational awareness, it is not sufficient. To avoid confounding basic aptitude with the effect of prior training in specific tasks, the elements that comprise the test must be unlike any real-world activities such as operating computers or controlling specific vehicles. Furthermore, the individual subtasks must be sufficiently simple to allow their mastery in a short practice period before combining them in the test situation. Sufficient situational complexity can be achieved by the manner in which the individually simple subtasks are combined in an adaptive scenario involving multiple sources of information and multiple response alternatives.

A complex-system operator must search for, evaluate, and integrate information about all relevant events, conditions, and resources, quickly assess changes in situational priorities, and allocate attention accordingly. To determine an individual's aptitude for meeting these demands requires a complex test in which high scores depend on:

- Finding out what's important now and in the long run and allocating priorities accordingly;
- Perceiving a situation correctly by avoiding preconceived assumptions and subjective biases and being vigilant;
- Discovering rules that are not explicit through induction and deduction;
- Recognizing serendipitous opportunities quickly and seizing them before they pass;
- Ignoring irrelevant distractions and tolerating frustration when things are going badly;
- Coping with the stress of high workload periods and poor performance indications; and finally
- Coping with the boredom of routine tasks and resisting complacency during periods of low workload.

WOMBAT-CS 3

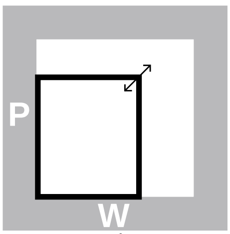
The Scenario

Overview

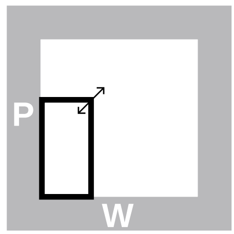
The PC-based **WOMBAT-CS Situational Awareness and Stress Tolerance Test**™ is designed to embody all the demands and constraints described in Chapter 2. The individual tasks involve target tracking, spatial orientation, pattern recognition and short-term (working) memory, and on each a testee can reach his or her asymptotic performance level after a short practice period.

The target tracking involves velocity or acceleration control of two display cursors to match generous error windows on the targets, making this test appropriate for assessing situational awareness rather than placing undue emphasis on motor skills. In a 3-D figure rotation task, two figures have to be rotated manually and/or mentally to reveal whether they are the same, mirror images, or different in some other way. In a quadrant-location task, as each pattern of numbers is learned, it is replaced by a different pattern of greater scoring worth. A two-back serial digit-canceling task is both tediously boring and frustrating.

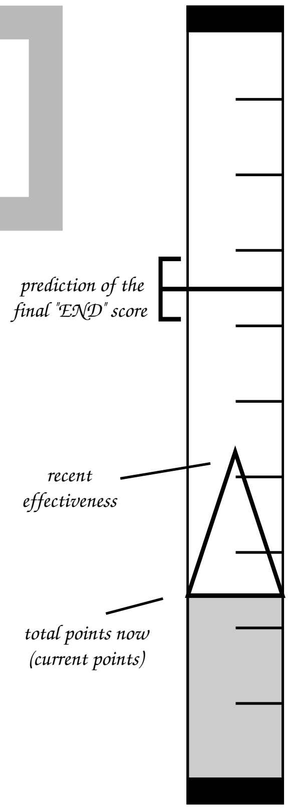
These tasks comprise the menu of scoring alternatives available to the testee on request. Each is relatively culture-free in that it has no real-world counterpart, and each can be learned quickly by the apt testee. **The attention demands of the WOMBAT-CS test are expanded by the ever changing information presented by peripheral indicators**. To score well the testee must monitor the peripheral indicators vigilantly to follow the shifting priorities of the various activities as indicated by their potential scoring worths and current scoring rates and to detect indications of failure modes that may require immediate termination of one activity in favor of another.



Tracking



Bonus



The testee's performance is monitored continuously during the test. Two Performance-Worth indicators are always visible in the top corners of the display and serve as guides to the testee in making the proper choices, establishing the best strategy, and monitoring scoring progress. The left indicator relates to the primary task (target tracking), and the right indicator shows the secondary (Bonus) task worth and performance level.

The product of the Performance (P) and Worth (W) represents the current scoring rate and is computed into an overall index of recent effectiveness that is also continuously displayed for the testee (shown at the right.)

An indication of total points now (current points) and a prediction of the final score (the "E" symbol), based on current points plus current effectiveness extrapolated for the time remaining, complete the thermometer-shaped total scoring display. While performing the WOMBAT test, the testee receives constant performance feedback and extrapolated outcome based on his/her previous choices. The testee is expected to make good use of these indicators in determining the best course of action.

THE PRIMARY TASK: TARGET TRACKING

Testees interact with WOMBAT-CS by means of a console containing two joysticks and a 13-button keypad. The keypad consists of 10 numeric keys (0-9), left and right arrow keys, and a key labeled “Bonus.” The right-hand joystick controls the position of a small cross on the screen and has a trigger switch that is used to engage an automatic tracking function (Figure 1). The left-hand stick controls the horizontal separation between two pairs of short vertical lines with fore and aft movements of the joystick.

Both sticks operate in either of two control modes. In the velocity control mode, the lines and the cross remain stationary until the sticks are displaced from their spring-centered positions,

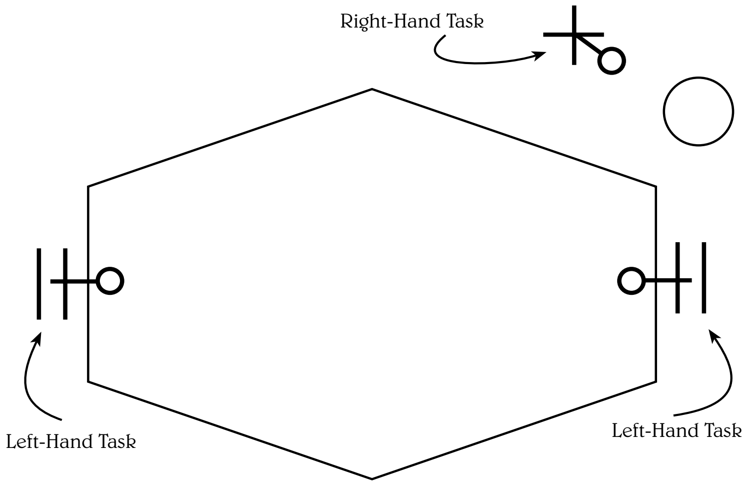


Figure 1. WOMBAT-CS Tracking Task. The left-hand task is to keep the two pairs of vertical lines on both sides of the vertical segments (targets) of an expanding and contracting hexagon drawn in the center of the display. The right-hand task is to keep the cross center inside the moving circle. Attached to the cursors are small "predictor" circles that show the directions and amounts of control inputs. The combined performances of the left and right hands multiplied by the current Worth of the task produces a Scoring Rate that is indicated by the area shown in the Performance-Worth indicator at the top-left of the computer display (as shown on Page 36.)

and the rates of movement of these symbols are proportional to the amounts of control displacement. In the acceleration mode, the symbols move at constant rates when the controls are centered, and the stick displacements determine the changes (accelerations and decelerations) in their existing rates of movement.

In either mode, the composite task is to track the vertical sides of an expanding and contracting hexagon with two pairs of short vertical lines controlled by the left stick, while simultaneously tracking a target circle with the cross controlled by the right-hand stick. The control mode (velocity or acceleration) changes automatically. At any time, the testee may encounter either of the two modes of control and must quickly diagnose the situation and respond accordingly.

To recap, in velocity control, stick displacement controls the speed of the symbol motion, and in acceleration control, stick displacement increases or decreases the speed of symbol motion, a relatively difficult dynamic relationship that requires concentration, patience, and a delicate touch.

The direction of motion relations for the right-hand are stereotypical (normally expected). However, the relationship for the left-hand is ambiguous (not normally expected) and must be learned: **forward for lateral expansion and backward for lateral contraction**. Attached to the cursors are small "predictor" circles that show the directions and amounts of control inputs.

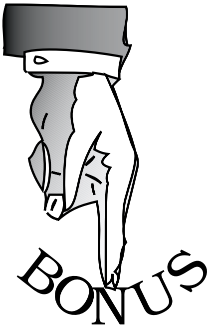
WOMBAT-CS's Autotrack Mode

If the targets are tracked within the indicated error limits, an automatic tracking function can be engaged with the right-hand joystick trigger to free the testee to pursue other methods for earning points. "Autotrack," however, is prone to failures that can vary in severity. Thus it must be monitored continually even though the testee is working on another task. When Autotrack fails, it does not disengage, but results in loss of tracking performance and a flashing of the tracking performance display.

One possible Autotrack failure produces tracking performance only a little less than can be achieved manually; in the other, Autotrack fails completely, and the cursors' motions continue without any regard for the locations of the targets. The testee will have to decide whether it is necessary to take manual control to avoid a serious loss of points in the event of a complete Autotrack failure or to continue performing another task of sufficient worth to offset the points lost from a minor deterioration of tracking performance.

When the failed Autotrack mode is "repaired" after a brief delay, it can be reengaged provided the manual tracking errors in all three dimensions are within the indicated target limits.

Secondary Tasks: The Bonus Pouch



There is another source of activity for the testee. Known as WOMBAT's "Bonus pouch," it is the source of three side tasks (each of one-minute duration), the performance of which can yield rewards and penalties in various forms. Any bonus task can be requested whenever the testee elects to move away from the primary task into this "secondary" level of activity.

The tracking task is "primary" in the sense that it cannot be ignored without serious penalty (the routine must be maintained), and the bonus tasks are "secondary" in that the testee may at any time suspend them and return to the tracking task without any penalty in the active bonus task when its play is resumed. The secondary tasks provide the problems and opportunities for the testee to demonstrate not only situational awareness and procedural compliance, but also spatial orientation with mental rotation, temporal and spatial pattern recognition, and short-term working memory.

The three selectable bonus tasks are:

- a 3-D **Figure Rotation** and matching task requires spatial orientation and mental rotation to discover similarities and differences in geometric figures (labeled "1" in Figure 2),
- a sequential **Quadrant-Location** task involves graphically presented temporal mazes in which a pattern of numbers recurs on successive trials until learned and then, when learned, each pattern is replaced by a different pattern to be learned (labeled "5" in Figure 2), and
- a Two-Back **Digit-Canceling** task of short-term memory (labeled "9" in Figure 2).

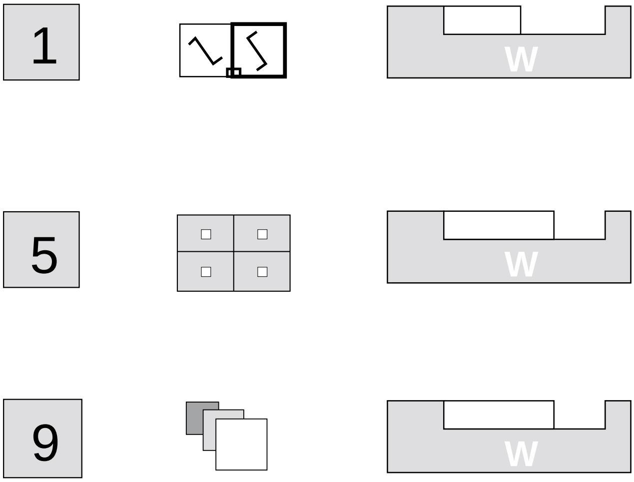
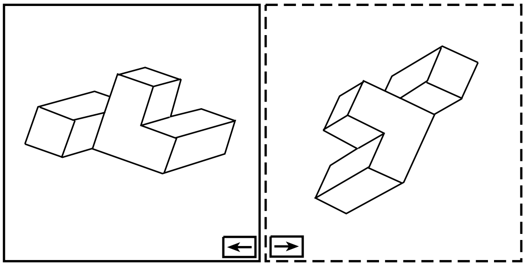


Figure 2. WOMBAT-CS Bonus Menu. Each of the three Bonus tasks is identified by a number, 1, 5, or 9, and by a pictogram to minimize the use of language and reduce the risk of culture-based biases. The widths of the horizontal bars to the right of the pictograms indicate the current relative Worths of the three tasks. Choosing and performing one task will reduce its subsequent Worth slightly and increase the Worths of the other two tasks accordingly.

Vigilance is an important aspect of situational awareness in the operation of any complex system, and vigilant time-sharing of attention is required during performance of any bonus task to catch and respond to Autotrack failures. Let's have a quick look at each bonus task.

The **Figure-Rotation** task displays two 3-D figures, side-by-side. One figure will be inside a solid square, and the other figure will be inside a dashed square. The solid square means that the figure can be rotated using the two sticks on the WOMBAT console; it is the "active" figure.

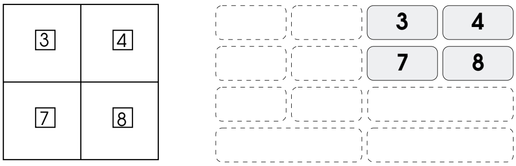
The testee rotates the active figure until he/she sees all the details of its construction. Then the testee transfers control to the other figure by pressing the right (or left) arrow key on the keypad (as appropriate), and studies it as well. The goal is to find out, as soon as possible, whether the two figures are identical, mirror images, or otherwise different. Maximum points are earned by selecting and entering the correct answer as quickly as possible.



When a correct answer is given the testee is offered the option of beginning another 3-D problem while there still is some time left. The testee should try to solve as many problems as possible during the one-minute trial. When an incorrect answer is given, no other problem is offered for the remainder of the minute.

In the **Quadrant-Location** task, the numbers "1" to "32" are placed in groups of eight in the four quadrants on the display. The task is to find each number in ascending order and press the button on the keypad that corresponds to the quadrant in which it lies, thereby canceling the numbers in sequence, 1 through 32.

The quadrant designation number appears in a box in the center of each quadrant. The "3" button corresponds to the upper-left quadrant, the "4" button to the upper-right quadrant, the "7" button to the lower-left quadrant, and the "8" button to the lower-right quadrant. The illustration shows the display quadrants and their respective keypad buttons.

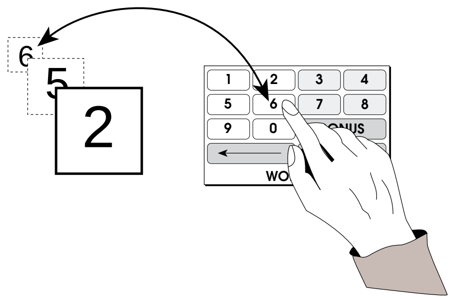


When all 32 numbers have been canceled (with few errors) before the end of a 60-second trial, the testee is offered the option of beginning another Quadrant-Location problem while there is still some time left.

The computer records and displays in the scores sheet the number of sequences mastered by the testee. Until a sequence is canceled efficiently, it reappears each time the Quadrant-Location task is chosen from the Bonus Menu. When a given sequence is mastered, a different one appears the next time the task is selected.

The Two-Back **Digit-Canceling** task briefly displays a single digit from 1 to 8 inside a square drawn in the center of the display. Starting with the third digit displayed, as soon as each new digit appears, the testee is required to press the key on the keypad matching the digit displayed two back in the sequence. Once the answer has been given, right or wrong, another digit appears, inviting the testee to match the next "two-back" digit in the sequence.

Each time an answer is given, the interval between the digits is adjusted according to how fast and how accurate the answers are. If the testee is accurate and fast, the interval will become shorter and the reward will increase. If the testee is wrong or slow, the reward decreases.



The testee must remember the digits as they briefly appear and must also remember the last two digits if an interruption becomes necessary to deal with the primary task. The illustration shows the action of answering digit "6" after "5" and "2" have appeared.

Testing Strategy

All four tasks, one primary and three secondaries, are relatively culture-free in that each is unlike anything called for in operating any complex real-world system, and each can be learned quickly by the apt testee. As you will see later in this manual, typical group learning curves on the WOMBAT-CS test initially show a slight, gradual improvement in the rate of scoring, with relatively uniform scoring after the third to fifth 10-minute segment.

The attention demands of the test are increased by situational information presented by the peripheral indicators (as seen earlier). To score well the testee must monitor the indicators vigilantly to follow the shifting priorities of the various tasks as indicated by their potential scoring worths and current scoring rates and to detect indications of failure modes that may require immediate termination of one activity in favor of another.

The task structure places a high premium on a rational attention allocation strategy. The background tracking task with its unreliable Autotrack generating a performance score on the appropriate indicator rewards the allocation of some portion of the testee's attention to the known signals of variability, namely, the changing worths of the different tasks and the running overall indices of current scoring and predicted final score.

How well the tracking and the bonus tasks are performed is important, but only in proportion to their momentary worths. To maintain high worths for all tasks requires that all be performed on a regular basis. To maintain maximum target tracking worth, bonus tasks must be performed frequently, and conversely, to maintain maximum bonus worth, Autotrack failures must be attended to quickly. Each time a bonus task is performed, it loses an increment of worth, and the others gain increments. As a result the testee's scoring rate depends more on what task is chosen moment-to-moment than on how well it is performed. The key to a high final score is effective management of the task worths.

The Origins of WOMBAT Bonus Tasks

We are frequently asked why we chose these particular Bonus tasks. Where did they come from? What do they measure individually?

Figure Rotation

"Mental imagery" tasks have received far more experimental attention than any other type in recent years, largely as a consequence of the brilliant work of Roger Shepard, the Ray Lyman Wilbur Professor of Social Science at Stanford University. Our figure rotation task is an adaptation of the task used, in the words of President Clinton (1995) in awarding Shepard the **National Medal of Science**, "For his creative theoretical and experimental work elucidating how the human mind perceives and represents the physical world and why the human mind has evolved to represent objects as it does ... ."

In 1968 the field of cognitive psychology was dominated by theories of artificial intelligence based on the assumption that all thinking involved the manipulation of discrete mental symbols. But Shepard was convinced that some thought processes were non-symbolic, that they are more like continuous simulations of external events. Then Shepard hit upon a great idea. Using solid block figures, he and two new graduate students, Jacqueline Metzler and Lynn Cooper, embarked on a series of experiments on mental rotation later reported in a bombshell paper in *Science* (Shepard & Metzler, 1971).

They had shown students pairs of pictures of objects in different spatial orientations. Sometimes the objects were the same and sometimes not, and they measured the time the students took to decide. The greater the difference in the orientation of the two objects, the greater the decision time. It became apparent that the students were making comparisons by "mentally rotating" one of the two objects into the same orientation as the other. The time differences even provided an indication of the rate of mental rotation.

But once again, there were wide differences in the mental rotation speeds of individuals, and these differences are believed to be directly related to how people perceive and interpret complex visual scenes in everyday life or in operating complex systems—as well as in the laboratory. Our Figure-Rotation Task differs from Shepard's in that the computer-animated figures can be rotated manually, but there are still wide differences in decision times depending on how much individuals rotate the figures manually versus their facility in mental rotation.

On August 5th, 2000, Roger N. Shepard was awarded the **American Psychological Foundation (APF) Gold Medal Award for Life Achievement in the Science of Psychology** for "*rendering objective and quantitative what had seemed irremediably subjective and qualitative—particularly through his invention of nonmetric multidimensional scaling and his introduction of methods of probing nonverbal internal processes and representations with external test stimuli, as in his chronometric studies of imagery, mental rotation, and apparent motion. His proposal that fundamental psychological principes—such as his exponential law of generalization and his least-path principle of mental transformation—have arisen as adaptations to universal features of the world points toward a psychological science partaking of the mathematical elegance and universality of physical science.*"

Quadrant Location

This pattern recognition test is an adaptation and extension of a paper-and-pencil test used by Professor Donald Johnson in an experimental psychology class at the University of Illinois in 1946. We have no idea where that test came from and have lost touch with Professor Johnson, but graduate students were mightily impressed with the wide individual differences in the scores of an already highly selected group of psychology students. Our version of the task has some of the characteristics of a temporal as well as spatial maze, and it is inherently motivating—people like it. The premium is on the quick recognition of each new pattern of numbers.

Digit Canceling

Running memory tasks have a long history, with much of the early work done in England. At Cambridge University, Harry Kay (1953) systematically investigated delayed digit canceling, with 1-back, 2-back, 3-back, and 4-back responses called for. Immediate and 1-back responses were almost without error. From 1-back to 4-back, error rates rose rapidly. The 4-back task was impossible for many; a few were able to develop rehearsal strategies that worked occasionally. Later it has been found that a longer interstimulus interval than Kay used allows some to handle the 4-back responses consistently.

For his Ph.D. dissertation at the University of Illinois, Robert North (1977) paired the 1-back task concurrently with each of three other tasks designed to measure immediate memory, classification, and tracking abilities, respectively. He also varied the priorities of the tasks and the difficulty of the tracking task to elevate the attention demands to the individual testee's saturation point. North's dual-task measures and others developed by Diane Damos (1972) proved effective in predicting pilot performance in primary flight training (notably, in experiments by North & Gopher, 1974, and Jacobs, 1976). The WOMBAT-CS test is an extension of their concept.

VALIDATION 4

IN QUEST OF THE IDEAL

The perfect system for selecting complex-system operators would have several qualities. It would be:

- **COMPREHENSIVE**, meaning that the system would not depend on any single attribute of successful complex-system operators but would address cognitive, psychomotor, and medical factors as well as situational awareness.
- **RELIABLE**, meaning that any test used would yield test-retest scores that are highly correlated.
- **DISCRIMINANT**, meaning that any test used would yield a wide range of scores normally distributed over the spectrum of human performance.
- **OBJECTIVE**, meaning that the scores of individual candidates would not be biased by the subjective evaluations of individual examiners.
- **CULTURE FREE**, meaning that performance on any test used would not be biased or otherwise affected by race, gender, or prior training and experience in operating specific complex systems.
- **VALID**, meaning that any test used in the selection system would measure what it is intended to measure, namely, the criterion of future success in complex-system operations.

The history of selection-test validation has been a frustrating exercise yielding, at best, quite modest results. The well-known criterion problem (discussed in the next section) is not the only culprit. Subjective measures such as interviews and peer ratings are notoriously unreliable and hence of low validity. Batteries of individual "basic abilities" tests have some predictive power but still account for only about 25 percent of the variance in training success and have no documented correlation with operational performance. The WOMBAT family has a theoretical basis supported by the experiments done at the University of Illinois in the '70s, and its demonstrated operational validity is strong evidence that this approach brings selection testing to a new level.

During the 1970's at the Institute of Aviation of the University of Illinois, 44 graduate students earned masters degrees and 18 earned doctorates based on experiments done at the Institute's Aviation Research Laboratory. Several of these experiments dealt directly with the predictive validity of various divided-attention tests calling for high degrees of situational awareness. In others, the same or similar tests were used to extract individual differences among trainees through analyses of covariance and thereby increase the power of the experiments.

The tests that showed the highest predictive validities were ones having much in common with the WOMBAT family. These tests involved multiple sources of information with shifting priorities calling for time-sharing and frequent reallocation of attention. In all cases the subtasks to be performed were unlike any subtasks in complex real-world systems. This was done both to guard against the possible transfer of skills acquired through prior training in operating specific devices or systems and to minimize any biasing effects from cultural differences due to race, language, physical activities such as sports, or computer facility.

The other key feature of such tests is that they must extend the testee to full attention-capacity saturation, at which point situational awareness is taxed to the edge of breakdown. To achieve this effect, such tests need to be automatically adaptive, increasing the flow of information and response demands until performance starts to deteriorate, then backing off to keep from crossing the threshold that leads to breakdown. The adaptive logic of the WOMBAT tests has been fine-tuned over the past decade to achieve precisely this necessary balance between stress and overload that keeps the testee working at his or her situational awareness limit.

For any organization involved in the training or hiring of complex-system operators, the first step in the selection process—before large sums have been invested in medical examinations and/ or operational testing in system simulators—should be the administration of WOMBAT-CS to screen out a majority of those who would never succeed as complex-system operators. Assuming the organization has a sufficient pool of applicants to draw from, it can then select those with high WOMBAT-CS scores who also satisfy the organization's other hiring criteria. If selecting from a large pool of already trained operators with comparable levels of experience, performance in system simulators may serve as the final screen.

Validation Requirements

The difficulty of developing tests of high predictive validity for operational aptitude involves several factors, the first of which is the usual clouding of operational performance criteria against which to validate any such test. As discussed in Chapter 2, if measures of operational performance are unreliable, there is no way that the true predictive validity of the test can be shown statistically. The pass-fail criterion is virtually useless when all operational personnel are given whatever amount of simulator refreshment is needed for periodic recertification, and rating scales are no better when almost everyone receives the same grade.

The objective evaluation of a test of situational awareness requires a valid criterion of operational success, one that is unlike any of our traditional validation criteria. Given the fact that instructors' ratings and pass-fail tests do not discriminate among operators accurately, where can the investigator turn? Surely measures of performance during training, no matter how objective, are not ideal criteria, because the ultimate purpose of aptitude tests is not to predict immediate success but *distant* future success as an operator of any complex system.

In an *ideal* validation study, a large number of applicants for complex system training would be tested, all would be trained, and all who completed training, whether certificated or not, would be assigned to specific jobs and their performances observed and evaluated objectively over an extended period. In addition, all would be retested on the original selection test, and a control group that received no training in the interim would be tested and retested to assess the effect of the first administration on the second. In the *real* world, none of these conditions, save the first, is practical.

Because a longitudinal study of all the same people over several years is not a feasible approach, an alternative plan may become necessary—one that will still address the predictive validity question in a realistic manner. One such approach is a stratified experimental plan in which independent groups of individuals representing the various stages in the sequence of training and increasingly complex operations are tested. The mean test scores for the successive groups are then compared statistically to assess the reliability of the anticipated successive increases in the group means.

A Stratified Pilot-Group Experiment

One study of this type has been performed with the WOMBAT-CS test at the University of Otago in Dunedin, New Zealand (O'Hare, 1997). An unusual opportunity presented itself in January 1995 when pilots from around the world participated in the Omarama Cup soaring competition at Omarama, New Zealand, preceding the 24th World Gliding Championships. David O'Hare of the University of Otago recruited fourteen of the competing pilots to demonstrate their situational awareness on the WOMBAT-CS Test.

Eight participants were classified as 'elite' pilots on the basis of their consistently superior performances in gliding competitions at national and international levels. Six of these were national champions competing at the World Championships. The other two were highly successful soaring competitors with distinguished careers as professional pilots with both military and test flying experience. Another six pilots were also highly experienced but without notable competitive honors. A control group of twelve nonpilots were closely matched with the pilots on the basis of gender, age, and occupational status.

The elite pilots had higher WOMBAT-CS scores than the other highly experienced but less successful pilots, and both pilot groups scored higher than the demographically matched nonpilot controls.

A score of 200 was a frequently used selection threshold for the version of the test used in 1995 by O'Hare (the usual threshold for Version 5.0 in current use is about 50% higher). None of the elite pilots scored below 200, and 62.5% of them scored above 250. Only one of the less successful pilots scored above 250, and two scored below 200. No control subject scored above 250, and 75% of them scored below 200. O'Hare concluded that, despite the relatively small number of subjects involved, the distribution of scores was significantly different from chance.

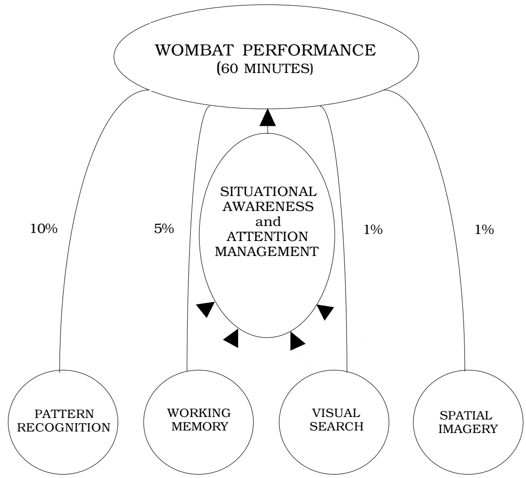


Figure 3. WOMBAT-CS Performance Model. David O'Hare created this model based on evidence that the strong relationship between high scores and elite pilot performance is relatively independent of so-called basic individual abilities (O'Hare, 1996, personal communication).

Prior to testing the glider pilots, O'Hare had investigated the relationships between the WOMBAT-CS scores of twenty-four nonpilot males, varying widely in age and occupational status, and their scores on four tests from the Walter Reed Performance Assessment Battery (Thorne, Genser, Sing, & Hegge, 1985). The tests were selected to measure the individual abilities hypothesized to underlie performance on the component tasks in WOMBAT, namely, pattern recognition, short-term (working) memory, visual search and recognition, and spatial imagery (Roscoe, 1993). The tests used were Pattern Recognition 2, Digit Recall, Six-Letter Search, and Manikin.

The only measure to correlate significantly with WOMBAT scores was pattern recognition, indicating that WOMBAT measures something not measured by basic ability test batteries. Figure 3 shows a model based on O'Hare's findings (1996, personal communication), which support the original premise that the individual tasks are relatively unimportant in the context of situational awareness. What is important is how those tasks are managed to maximize the rate of scoring. To be sure, the ability to perform the tasks has an impact on scoring, but its contribution is secondary to the management of the relative worths of the tasks.

In a recent study, O'Hare (2000) found that WOMBAT-CS scores reliably predict early performance on TRACON, an air traffic control task that requires high levels of SA. He also found that 28 percent of the variance in scores was accounted for by general intelligence ("g"), thus leaving 72 percent to be attributed to other sources. He found no evidence that WOMBAT scores depend on age (over the range included), on experience with conputers or computer games, or on any specific underlying ability, except for its sizeable overlap with general intelligence. The remaining variance is attributed to SA.

O'Hare is following with an investigation of the differences between high and low WOMBAT-CS performers, using the TRACON task in a training paradigm involving the "emphasis change" strategy advanced by Daniel Gopher (1993). Initial findings show a significant interaction ($p < 0.05$) between the pretraining and posttraining scores of high and low WOMBAT performers relative to those of a control group who receive no emphasis change training. Those with already good attention awareness and management strategies (high SA scorers) benefit little from the training, whereas those with low SA scores benefit more.

O'Hare concludes that his studies offer preliminary support for the notion that the WOMBAT-CS test measures an aspect of SA "beyond basic intelligence and motor skills" (Roscoe et al, 1997, p. 11). Evidently this ability is related to the management and control of attention.

Additional fragmentary evidence of the near-term predictive validity of WOMBAT-CS was recorded by Gavan Lintern (1994) at the University of Illinois. Correlations of -0.80 and -0.78 were found between WOMBAT-CS scores and, respectively, the number of practice landings and the number of flight hours required before flying solo; those with the higher WOMBAT-CS scores required fewer practice landings. Predicting performance in training is easier than predicting future operational performance, but these results do suggest that WOMBA-CS measures an aspect of situational awaremess.

5

Installation of WOMBAT-CS

The following chapters are intended to assist the supervisor in charge of the WOMBAT-CS implementation. Described are different procedures regarding:

- proper installation techniques,
- how to run the software,
- language issues,
- accessing and understanding the scores,
- running an in–house validation program,
- contacting the ÆRO INNOVATION Technical Support Department for supplementary information.

To benefit fully from the second part of this book, the reader should know the following basic MS-DOS commands and <keyboard keys>:

- **<Enter>**
- **<ESC>**
- **A: B: C:**
- **CD**
- **CD**
- **DIR**
- **DIR/W**
- **DIR/P**
- **DEL**
- **EDIT**
- **COPY**
- **XCOPY**
- **<CTRL BREAK>**
- **AUTOEXEC.BAT**

Installation

WOMBAT-CS runs on most PC–Compatible computers. If you need to install WOMBAT in a computer other than the one supplied by Aero Innovation, please refer to the annex at the end of the present manual. You may contact Aero Innovation Technical Support for the proper installation procedures and the latest updates on the WOMBAT-CS program. The phone number is +1 514-336-9310, the email connection is: info@aero.ca and technical information is also found on the Web at: http://www.aero.ca.

Each WOMBAT-CS system requires:

- a PC–Compatible computer equipped with a math coprocessor (not required with Pentium-equipped computers) that also contains the following:
  - — an internal hard disk
  - — a high density 3.5" floppy disk drive labeled "A:"
  - — a VGA 512kb (min) graphics board
  - — an ISA 8-bit WOMBAT interface card (supplied) equipped with one DB-25 socket connector
- a keyboard
- a VGA color graphic monitor
- a WOMBAT console (supplied)
- a 2-meter long DB-25 connector cable (supplied)
- an optional WOMBAT Parallel-Port Interface (WoPPI) that replaces the ISA 8-bit interface card and connects to the parallel port of the computer, such as a laptop.

If you unpack the computer from Aero Innovation, check that it has all the internal components listed above installed. Choose a quiet environment for WOMBAT-CS where the candidate can be left in isolation while he/she takes the test. Arrange the console on a table in a comfortable position. Connect the color monitor and the computer keyboard, then plug the DB-25 cable into the connector on the interface board. Push it home firmly taking care not to bend any of the pins. The plugs are polarized, so that each end can have only one position. Connect the other end to the socket on the console. At this point the computer and monitor can be turned on.

LAUNCHING WOMBAT-CS

We have stored the WOMBAT-CS program and all the necessary files in a subdirectory named after the version of the WOMBAT-CS program current at the time of shipment. For example, Version 5.0 of WOMBAT-CS will be stored on the hard disk of your computer in a directory named **WOMBATCS.V50**.

Subsequent updates of the program can be stored in different directories to insure a smooth transfer from old versions to new ones, prior to deleting superseded versions. To run WOMBAT-CS, switch to the appropriate subdirectory, the one that contains the WOMBAT-CS software, by typing:

CD WOMBATCS.V50 <Enter>

The screen will then show:

C:\WOMBATCS.V50>

If you received your computer from Aero Innovation, or if you installed new WOMBAT-CS software using the supplied installation routine, then the batch command **WOMBAT.BAT** will load in sequence everything that is required for the WOMBAT-CS test. Just type:

WOMBAT <Enter>

and you will have **HARDWARE**, **METAWINDOW** and **WOMBAT-CS** in the appropriate sequential order. You can also invoke a fresh WOMBAT-CS session by typing the same command stored in the **WOMBAT.BAT** batch command:

WOMBATCS <Enter>

THE HARDWARE™ PROGRAM

The procedures described in this manual will ensure that each time you invoke the WOMBAT-CS program the diagnostics software named **HARDWARE**™ will appear on the monitor. You can also invoke this program whenever you want by typing the command **HARDWARE <Enter>**. This self-explanatory program is used to verify the integrity of all the cable connections and hardware assembly before you begin the WOMBAT-CS test. While watching the screen:

1. Move systematically each joystick and observe that full deflection causes the associated red cursor to be displayed full scale. Also check that each motion has no effect on any other axis. A noticeable delay between your hand motion and the cursor movement is an indication that there is a problem with the associated joystick and that **the test should not be administered**. Contact Aero Innovation for a replacement joystick.
2. Activate each of the joysticks' thumb and trigger switches and observe the respective red cursors appearing and disappearing on the scales.
3. Press each button on the WOMBAT keypad and observe the change of color of the respective keys on the screen.

HARDWARE™ will verify the integrity of the circuitry of each control you use. You can access its HELP by pressing the F1 key on the computer keyboard. Once the hardware test is satisfactory, press the ESC key on the computer keyboard to exit the program **HARDWARE**™. You are then ready to enter the WOMBAT-CS test.

If one or more connections do not test properly, please make sure that the supplied DB-25 cable is properly connected and fastened to both the console and the WOMBAT computer interface connector located at the back of the computer. The interface card is marked "WOMBAT" just below the DB-25 connector. Be careful not to connect the cable from the console to the parallel printer connection on the back of the computer, which uses the same connector type as the WOMBAT interface card.

If the cable doesn't seem to be the problem, something might have happened during shipping. Please call Aero Innovation's

Technical Support Department. During the warranty period do not open the WOMBAT console without prior authorization from an Aero Innovation Technician.

WOMBAT-CS's Graphics Environment

The WOMBAT-CS program needs a graphics environment named METAWINDOW to run properly. Although the command to load METAWINDOW is normally stored in the batch command **WOMBAT.BAT**, you can manually load it by typing:

METASHEL/I <Enter>

The graphics environment will remain loaded until the command:

METASHEL/K <Enter>

is used to unload it or the power is turned off. These two commands will only work if MS-DOS can find the program METASHEL in the current directory or somewhere that the path environment variable points to. Refer to the MS-DOS User Manual for details on paths.

Running WOMBAT-CS

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Reference String and File Annotation

When WOMBAT-CS is launched as a new start, the user is asked to enter a reference string and a file annotation and then to confirm the current date. This Year 2000 protection allows you to run WOMBAT on non-Y2K compliant computers without negative consequences on the date value saved in the test results. The mandatory reference string is used by the program to create a DOS file for the storage of the test results. If the string has a "." then the string as you enter it will be used to name a DOS file. If there is no "." in the string, then **.SCR** (for **SC**o**R**e file) will be added to the end and used to name a DOS file. In both of these cases an error will be generated if the string is not a legal DOS name (such as a maximum of 8 characters.)

It is recommended that you create and maintain a consistent system for determining a unique reference string assigned to each person tested. One example of such a system is using secret codes while keeping track of the relation between these codes and the names of the applicants in a separate, confidential file (the "key").

The file annotation is optional and can be any message up to 30 characters long. The information is only copied by the program into the final results file for future reference. If you do not wish to enter a file annotation, just press **<Enter>**.

Within a given scores subdirectory, if WOMBAT-CS detects another file with the same name as the one created from the reference string, you will be asked to decide whether to erase it or to go back and reenter a different reference string to avoid duplicating the file name. This check only guarantees that the current scores file will not overwrite any other scores file existing in the **current scores subdirectory**. If you decide to erase an old scores file at this point, the data collected and stored under that filename in the **composite spreadsheet data file** will remain, thus creating two records (or rows of numbers) with the same scores filename (see **Composite Spreadsheet Data File**). It is therefore good practice not to erase an old scores file and to select another reference string if prompted to do so.

It is highly recommended that you periodically archive (or backup) the score files. If you are currently in the WOMBATCS.V50 subdirectory, the command to archive scores files onto a floppy disk in drive A: is:

XCOPY RESULTS.DIR A:\RESULTS.DIR\ <Enter>

This command will send all the files contained in **RESULTS.DIR** to the floppy disk in drive A:. It will even create the directory RESULTS.DIR on the drive if it doesn't already exist. Of course, you can always revert to a MS Windows™ interface and use the mouse to copy whole directories onto floppy disks. To delete the specific scores file **1234.SCR** from the **RESULTS.DIR** directory, the DOS commands are:

CD RESULTS.DIR <Enter>
DEL 1234.SCR <Enter>

or just:

DEL RESULTS.DIR\1234.SCR <Enter>

Refer to MS-DOS manuals for more information on the use of the **COPY** and **DEL** commands as well as the use of wildcards * and **?** in filenames.

THE WOMBAT.CFG FILE

Locate the file named **WOMBAT.CFG** in the **WOMBATCS.V50** subdirectory. This text file lists important parameters controlling a number of functions. The file delivered with Version 5.0 is shown in Figure 4.

WOMBAT.CFG is a user-modifiable text file. You can use your favorite word processing package (but be careful not to add any formatting codes to the text) or a simpler application such as the DOS Editor to open and modify the contents of a text file. For example, at the DOS prompt, type:

EDIT WOMBAT.CFG <Enter>

Figure 4 shows what you can expect if you open the **WOMBAT.CFG** file. Each parameter is self-explanatory. If you collect WOMBAT data on more than one WOMBAT station, there is a question about where you will maintain a single archive of all the scores files. **WOMBAT-CS's embedded safety features do not insure that duplicate names will not be on some other WOMBAT station**. Consequently copying all scores together from different stations could result in loss of some scores files with duplicate names. For this reason we suggest that you use a unique scores subdirectory name on each of your WOMBAT stations. Then copying each subdirectory to the single archive will keep the files from different stations from ever mingling.

```
 * See the manual for advice on changing the parameters in this file *
562 The code for a standard VGA display (see README for others)
60 is the whole number of minutes of instruction time (1 or more)
10 minutes for each scoring interval (1 to 90)
9 scoring intervals in the complete test (1 to 90)
2 composite data file order (1 = .SCR file order; 2 = grouped scores)
RESULTS.DIR is the name of the scores subdirectory
COMPOSIT.TXT is the name of the composite spreadsheet data file
RESEARCH.TXT is the name of the research data spreadsheet file
? language directory to be used
```

Figure 4. The WOMBAT.CFG File as Delivered.

If you decide to change any of the following:

- the interval duration,
- the number of intervals, or
- the composite spreadsheet data file order

through their respective parameters in the **WOMBAT.CFG** file, you should also change the default name of the composite spreadsheet data file and/or the name of the default scores subdirectory. Either of these actions will produce a new composite spreadsheet data file with headers appropriate to the parameters. That way the new data will not be appended to a composite spreadsheet data file that is only appropriate for the old parameters.

Time Required, Time Allowed

The **WOMBAT.CFG** shown in Figure 4 specifies that the WOMBAT-CS test is to run during 9 consecutive intervals of 10 minutes each for a total of 90 minutes. Moving from one interval to the next is invisible and goes unnoticed by the candidate. At the end of each interval, WOMBAT-CS records the scores in the scores file and the temporary composite spreadsheet data file, **WOMBATCS.SPD**.

At the end of the test the overall scores are also recorded in the scores file and the complete set of all scores is added to the end of the composite spreadsheet data file. If the composite spreadsheet data file does not exist at this time, it is created with a first record containing column headers that are appropriate to the kind of data being collected. After writing the composite spreadsheet data file, the temporary file **WOMBATCS.SPD** is erased.

Research organizations may wish to vary the number and duration of intervals. Modifications must be made carefully as they will affect the way scores are labeled inside the composite spreadsheet data file. It is highly recommended that you change the scores subdirectory **parameter** each time you change one or more of the parameters mentioned above. This will insure that tests administered according to new parameters will have their scores saved into an independent subdirectory, and consequently in a new spreadsheet data file, thereby protecting any previous data. Feel free to discuss this issue with an Aero Innovation representative before altering the number and duration of the intervals.

The following pages assume the default settings found in the **WOMBAT.CFG** file upon delivery are being used, namely, the length and number of intervals and the names of the scores subdirectory and the composite spreadsheet data file: **RESULTS.DIR** and **COMPOSIT.TXT**, respectively. Also assume that the reference number 1234 has been assigned to a candidate and is supplied to WOMBAT-CS Version 5.0 at the startup screen.

Instruction Time Limitation

Candidates go through a succession of instruction pages and accompanying exercises, each being known as an **instructional phase**. These instructional phases constitute the complete **instructions period**. The default time limitation for the instructions period is 60 minutes. You can make the instructions period longer or shorter to suit your requirements by editing a new value into **WOMBAT.CFG**.

Present users of WOMBAT-CS tell us that the use of the **Candidate Manual** before the test shortens the time spent reading the on-screen instructions. We recommend that you distribute the Candidate Manual one week ahead of time to allow the testees to read it carefully.

Test Duration

By default, the test duration is 90 minutes divided in 9 intervals of 10 minutes each. This duration does not include the time spent in the instructions period. The interval duration parameter and the number of intervals parameter are both found in the **WOMBAT.CFG** file (Version 4.3 & up). We recommend that you DO NOT shorten the **total test duration** (determined by the number of intervals times the duration of each) until you have acquired sufficient data to assess the consequences of administering a shorter WOMBAT-CS test. Please contact an Aero Innovation representative to discuss the possibilities of shortening the test.

Immediate Exit

Pressing and holding the Control key (CTRL) and then pressing the Break key on the computer keyboard will immediately terminate a WOMBAT-CS session at any time in the instructions period or during the test. The incomplete data collected to that point will be stored in the scores file and the composite spreadsheet data file in the current scores subdirectory.

Exiting and Restarting a WOMBAT-CS Session

To accommodate the possible need to break the instructions and testing into two separate periods, a mechanism for exiting and then restarting a session has been included (see Figure 5). If the **ESC** key is pressed **anytime before the testing begins**, the program will stop when the testee has spent all the time allowed or when "9" and "0" are pressed. The time spent in each of the instructions phases is then written to the scores file and the program is suspended.

The previously exited session of candidate **1234** can be re-invoked by typing: **WOMBAT 1234 <Enter>**

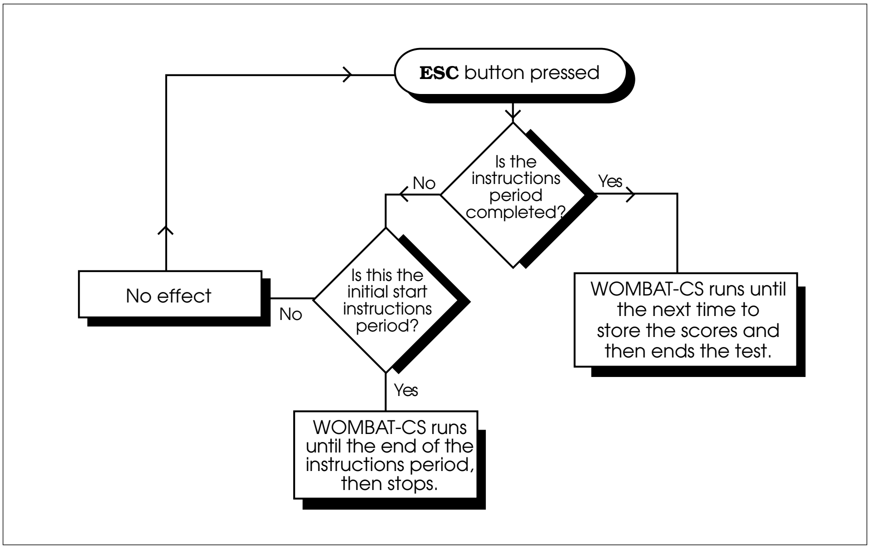


Figure 5. The Use of the ESC Button.

The system will search for the file **1234.SCR** created during a previous session and stored in the current scores subdirectory. If the file is not found, the program stops with an error message (Figure 5.) If the file is found, the program will append the new data to the end of the previous data in the file, no matter whether the previous session was a complete test or a shortened test. There is no limitation to the number of sessions that can be appended to a single scores file.

If the file **1234.SCR** is present in the current scores subdirectory, the instructions period is entered near its end and the user is given up to 10 minutes of additional practice. During this practice, the scheduled exit mechanism is disabled. That is, pressing **ESC** will have no effect. After the 10 minutes are up, the test begins and can be stopped by the second escape mechanism to be described below.

Shortening the WOMBAT-CS Testing Time

A second mechanism for scheduling an escape has been included in WOMBAT-CS. **During the test**, it is possible to terminate early by pressing the **ESC** key on the keyboard (see Figure 5). The exit is queued for the next point when scores would be stored on the disk up to the maximum time of the test (i.e. the end of the current interval). A message will appear at the bottom of the screen giving the exit time that has been queued.

Uncontrolled Program Exit

If a program problem, a hardware failure, or a power failure results in an unscheduled exit from the program, the normal exit process for saving the latest data to the scores file or the composite spreadsheet data file will not take place.

If there are any on-screen messages, they should be copied before taking any futher actions. The directory of the WOMBAT-CS program should be examined at the earliest opportunity for the temporary file **WOMBATCS.SPD**. If it is found, it contains a record of the last scores saved before the unscheduled exit and should be copied somewhere (possibly with a new name) before the program is run again to collect WOMBAT data; otherwise it will be replaced with the new data.

If you save the temporary file left by an unscheduled exit, there are ways to incorporate the data into the composite spreadsheet data file, which an Aero Innovation representative can help you with if you want.

LANGUAGE ISSUES 7

The text that appears during the instructions and during the test has been stored in text files inside language subdirectories on the computer's hard disk. You can have as many language subdirectories as you wish (see Figure 6), each one containing all the files of one language.

THE BATMSG FILES

As seen in Chapter 7, the instructions period consists of instructional pages and accompanying exercises, both of which are called **phases**. Each instructions page comes from a separate file. There are as many text files as pages of text in the instructions period.

Each file is named **BATMSG.x**, where x is a number between 000 and 999. You must not change the name of any BATMSG file. Accompanying exercise phases have no text associated with them.

The BATMSG files are standard user-modifiable ASCII files. You can use your favorite word processing package, or a simpler application such as the DOS Editor to change the text in any of the files. For example, to edit the text found at Phase 3 of the instructions using the DOS Editor, at the DOS prompt type:

EDIT BATMSG.5 <Enter>

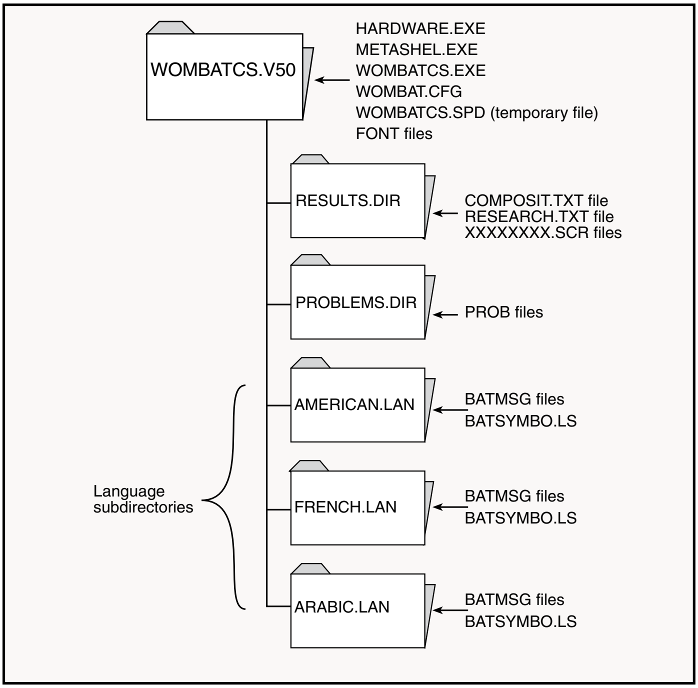


Figure 6. WOMBAT-CS File Structure as Delivered. This figure represents the subdirectory structure and the enclosed files as delivered. RESULTS.DIR and COMPOSIT.TXT are default names for the scores subdirectory and the composite spreadsheet data file, respectively. There are virtually no limitations on the number of language subdirectories you can create. To be recognized by the program, each language subdirectory must be located inside the WOMBATCS.V43 directory and have its name end with the suffix LAN.

With the **EDIT** command, you have access to the text of any BATMSG file and can make all the editorial changes you want, provided that you **don't add too many lines** of text to the file and that each individual line **ends with a carriage return** (CR). Keep in mind the fact that WOMBAT-CS uses fixed width characters and uses both the text mode of the terminal and the graphics fonts displayed by METAWINDOW. If new lines are added to the file, some lines from the top of the page could go out of sight once invoked by WOMBAT-CS. In this case, just edit the same file again and reduce the number of lines of text. The limit on the number of lines varies depending on the contents of the screen.

If one or more lines of text in a BATMSG file is longer than 80 characters, the WOMBAT-CS will suffer from a fatal runtime error and crash. In this case, identify which BATMSG file is defective and insert a carriage return at or before the 80th character of that line. A few message screens must be limited to 76 or fewer characters or else there will be conflict between graphics elements of the display and the text.

Remember not to delete any BATMSG files in a given language subdirectory.

The BATSYMBO.LS File

In each language subdirectory, there is a text file named **BATSYMBO.LS**, which contains a list of words or short sentences used by WOMBAT-CS to display commands, menus or comments in the program. Some of the words of BATSYMBO.LS will appear inside colored rectangles during the test, like the words TRIGGER, AUTOTRACK, or BONUS. See a printout of the American English version of BATSYMBO.LS in Appendix 2.

If you take a look at the BATSYMBO.LS file using the **EDIT** command, you will see that some lines begin with one or more key words, followed (either on the same line, or on the next indented line) by a comment to help you understand the meaning or context of the key words. Sometimes, a **Maximum Number of Characters** will be specified to indicate the maximum length of the words, so they fit inside the colored rectangles when displayed in the test. If the comment is the next line then the whole preceding line is read into a string and the program attemps to display the whole string. Sometimes the string is centered in the available area and other times it starts at the left edge of that area.

If you change or translate some or all of the key words contained in the BATSYMBO.LS file, make sure that you change ONLY the key words, nothing else. The number of lines in the file and their order must remain unchanged for WOMBAT-CS to run without problems.

TRANSLATING WOMBAT-CS

WOMBAT-CS is normally delivered in American English and Canadian French languages. WOMBAT-CS can also display several other languages if certain conditions are met. Languages based on the Roman, Cyrillic, or Arabic alphabets can easily be used in the **BATMSG** files. Other languages, such as the ones based on Japanese or Chinese characters may possibly be used with some restrictions. Contact Aero Innovation's Technical Support for more details on translating WOMBAT-CS.

On occasion, it may be more cost-effective to translate the printed documentation only, such as the Candidate's Manual, which follows, step by step, the WOMBAT-CS instructions. Encapsulated PostScript (EPS) graphics and Adobe PageMaker™ 6.5 templates are available free-of-charge through Aero Innovation for both MS Windows 98 and Apple MacIntosh platforms to help you publish your own version of the WOMBAT-CS Candidate Manual.

If you want to add a new language to your WOMBAT-CS software (German in the following example), proceed as follows:

- At the **C :\WOMBATCS.V50>** prompt, type:
  XCOPY AMERICAN.LAN GERMAN.LAN\ /V <Enter>
  Then type the following command:
  CD GERMAN.LAN <Enter>.
  This action will create a whole new set of instructions, located inside a new subdirectory labeled **GERMAN.LAN**.

- Translate <u>one by one</u> all the BATMSG files in German using the **EDIT** command. Just overwrite the BATMSG files, don't remove any BATMSG file.

- Translate desired words in the BATSYMBO.LS file, again using the **EDIT** command.

- Once a few files are translated, and once the **BATSYMBO.LS** file is translated and saved, launch **WOMBATCS**. You will see at the top of the monitor the new language menu showing the German addition. Choose it and start the program to check the translation done to that point. You can have **different versions of the same language** to suit different needs, clients, or populations. Just follow the procedure above and give each subdirectory a unique name with the LAN suffix (such names are restricted to 8 characters before the dot).

If you intend to edit the original distribution files in **AMERICAN.LAN**, we suggest that you make a copy of that subdirectory with some other name so you don't lose the originals. They are your reference to the ideas we have thought appropriate to cover in that instruction phase.

Blank Page

THE WOMBAT-CS SCORES

8

READING THE SCORES FILE

You can access the desired scores file, either with a word processor program or, if you are in the current scores subdirectory, by typing:

EDIT 1234.SCR <Enter>

Each scores file is divided into two sections. The first part contains a table of instruction phases and associated elapsed times in milliseconds. WOMBAT-CS keeps track of the total time in milliseconds the candidate devoted to each phase of the instructions, and prints it next to the phase number. At the present time, there is little known benefit to an operator to record or use these times. Such data may be found useful in scientific studies in the future.

The second part is a table of incremental scores collected for each scoring interval during the test and the last interval if the test was exited before a normal scoring interval. The last line has the summary scores for the whole test. Referring to Figure 7 on a later page, you will find:

- The **Interval** (ms) is the duration of the data collection period in milliseconds. The default interval is 10 minutes. The default WOMBAT-CS test consists of 9 scoring intervals for a total of 90 minutes.

- The **Tracking Score** (TS) is calculated as the Tracking Worth multiplied by the Tracking Performance. The TS depends not only on performance but also on the frequent playing of bonus tasks to maintain a high Tracking Worth.

- The **Tracking Performance %** (TP) figure reflects the efficiency of both the candidate and the Autotrack at tracking the moving targets. 100(TS/TP) = **Perfect Tracking Score** (not shown on the scores sheet.)

- The **Figure Rotation Score** (FRS) is the amount of bonus points earned from the Figure-Rotation task (Bonus Performance multiplied by Bonus Worth.)

- The **Quadrant-Location Score** (QLS) is the amount of bonus points earned from the Quadrant-Location task (Bonus Performance multiplied by Bonus Worth.)

- The **Sequences Mastered** (SM) is the number of Quadrant Location sequences that were mastered.

- The **Digit-Canceling Score** (DCS) is the amount of bonus points earned from the Two-Back Digit-Canceling task (Bonus Performance multiplied by Bonus Worth.)

- The **Total Bonus Score** (TBS) is just the bonus component of the overall score and is the sum of the QLS, FRS, and DCS.

- The **Overall Score** (OS) is the sum of TS and TBS. It is the Overall Final Score that should be used when selecting candidates (330.3 points in Figure 7) The other results are shown mostly for scientific research purposes.

- The **Predicted Final Score** (PFS) is computed from the overall score to the present time and the scoring rate for the current interval extrapolated to the end of the test.

```
Sir Winston Churchill

WOMBAT-CS Version 5.0
Initial Instruction Phase - Date: 1/16/1944
Using filename: RESULTS.DIR\1234.SCR
And composite spreadsheet data file: RESULTS.DIR\COMPOSIT.TXT
And research-data spreadsheet file: RESULTS.DIR\RESEARCH.TXT



Instruction phase and elapsed time in milliseconds

 1   88523         2   56107         3      46862         4   30222         5   18240
 6   29688         7  154960         8      60591         9   24307        10   31192
11   25652        12   27533        13      11465        14   15549        15   23099
16   30613        17   11317        18      30677        19   11096        20   30409
21    3439        22   30971        23     108772        24   90885        25    4179
26   30521        27    8022        28      45127        29    1592        30   45169
31   46157        32   31530        33      22902        34    8986        35   19164
36   69622        37   48042        38      63922        39   17079        40   61731
41   65268        42   83833        43      41705        44   88063        45  120579
46   54651        47   35666        48      18841        49   40462        50   11011
51  194893        52       0        53          0        54       0
2+...+50 33 minutes and 7 seconds



Test Phase

1. Interval (ms)          2. Tracking Score           3. Tracking Performance (%)
4. Figure-Rotation Score  5. Quadrant-Location Score  6. Sequences Mastered
7. Digit-Canceling Score  8. Total Bonus Score        9. Overall Score
10. Predicted Score

         1        2       3        4        5     6       7        8        9      10

    600003     22.0    98.7      1.1      4.5     0     4.9     10.6     32.6   293.2
    599997     21.8    97.7      4.5      3.6     0     5.7     13.7     35.5   316.5
    600000     21.9    98.1      5.0      5.3     0     4.4     14.8     36.7   324.8
    600003     21.8    98.0      3.7      4.2     1     7.1     14.9     36.9   325.8
    599997     21.3    95.7      3.9      9.0     1     4.9     17.7     39.7   339.9
    600000     21.6    96.8      2.5      5.3     0     5.5     13.7     34.7   320.1
    600000     21.9    98.0      3.6      5.3     1     6.3     15.2     37.3   327.8
    600000     21.8    97.8      4.9      5.4     0     4.6     14.9     37.6   328.4
    600001     22.1    98.9      5.7      5.8     0     5.7     17.5     39.5   330.3
   5400001    196.1    97.7     34.9     48.4     3    49.0    132.9    330.3
```

Figure 7. WOMBAT-CS Scores Sheet. Actual scores sheet at the completion of a WOMBAT-CS 5.0 test of 90 minutes. To view a scores sheet, simply use a word processor or text editor program. This scores sheet is named 1234.SCR and is found in the RESULTS.DIR subdirectory on the computer's hard drive in the WOMBATCS.V50 subdirectory.

Spreadsheet Data Files

Whenever the number of tests justifies it, we recommend the use of a commercial spreadsheet or database program to help you analyze the scores of your candidates. Such commercial packages include Excel™, Lotus 1-2-3™ or DBase™ to name just a few. Not only will it be easier to compare one candidate's performance against the group, but you will be able to view the candidate's progression in the test by plotting the score intervals onto a graph, as shown below.

Inside the scores subdirectory (default **RESULTS.DIR**), you will find the **composite spreadsheet data file** (default **COMPOSIT.TXT**) and the **research spreadsheet data file** (default **RESEARCH.TXT**).

The **composite spreadsheet data file** contains the scores from each test conducted from a WOMBAT-CS subdirectory provided WOMBAT.CFG called for adding spreadsheet data to a file with this name. Each time a test ends, a line of data is appended to the composite spreadsheet data file. If you rename or delete this file from the scores subdirectory, WOMBAT-CS will create a new file automatically using whatever name is specified in WOMBAT.CFG (this may be required if you modify some parameters in the WOMBAT.CFG file). While you are archiving all the files containing results, consider renaming the composite spreadsheet data file after a relocation to avoid overwriting it with another file of the same name later.

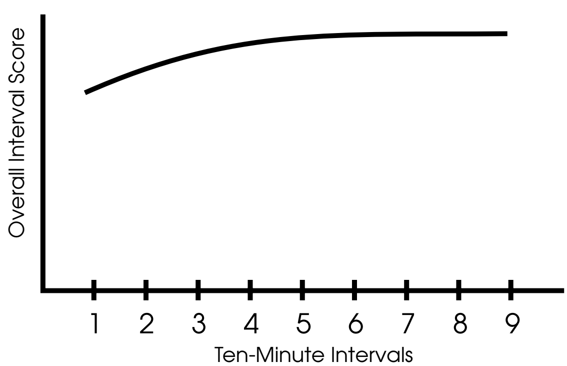


Figure 8. Typical WOMBAT-CS Group Learning Curve.

The **research-data spreadsheet file** is similar in format to the composite file, but it contains data to be used by psychometrists during scientific studies. No data contained in this spreadsheet file should be used in isolation for selection purposes. The test administrators usually share the data contained in this research file with Aero Innovation and with other psychometrists for the purpose of improving the test's scoring algorithms.

The data contained in both spreadsheet data files are saved in columns (vertical) delimited by tabs and rows (horizontal) delimited by carriage returns. To open the file, first launch your spreadsheet application, then select OPEN from the FILE menu and locate the desired composite spreadsheet data file. Once the loading is completed, you will observe a number of long rows of data. The first row on top contains all the column labels, and each subsequent row represents one WOMBAT-CS test. The data numbers are exactly the same as in the .SCR files; they were just formatted so as to speed up spreadsheet loading operations and avoid error-inducing retyping.

Scores-File Order vs Grouped-Scores Order

There are two different orders for the data in a row as controlled by the composite data file order **parameter** in **WOMBAT.CFG**. In the *scores-file order,* the data shown in Figure 7 are written into the spreadsheet from left to right on each line and from the top to the bottom through all the lines.

In the *grouped-scores order,* the instruction phase times are written in the farthest right columns of the spreadsheet, and the test data are written from top to bottom of each column of the table and from left to right through the table columns. This results in interval times being in adjacent spreadsheet columns followed by all tracking scores and so on.

How Predictive is WOMBAT-CS in My Operation?

To answer this question, you will have to conduct a comparison between the WOMBAT-CS scores and ratings based on a recognized criterion such as a standardized performance test administered at a specified level of training or operational experience. The criterion performance requirements for the test must be clearly understood by the candidates and understood and agreed to by the evaluators who will rate the candidates.

To assure maximum objectivity, at least two and preferably three isolated evaluators should make and record simultaneous, independent assessments of the same test performance by each candidate. Once both the performance ratings and the WOMBAT-CS scores are completed, a statistical correlation or regression analysis will show how well WOMBAT-FC predicts the criterion.

For a meaningful validation study, test 40, 50, or more candidates at some specified level of training or operational experience. Have each evaluator independently select the top and bottom 4% of the total number tested and assign them ratings of 5 (best) and 1 (worst), respectively. Then have them assign ratings of 4 (good) to the next best 24% of the group and ratings of 2 (poor) to the next worse 24% of the group. The middle 44% will receive a rating of 3 (average). Then take the means of the ratings of each candidate by the independent evaluators.

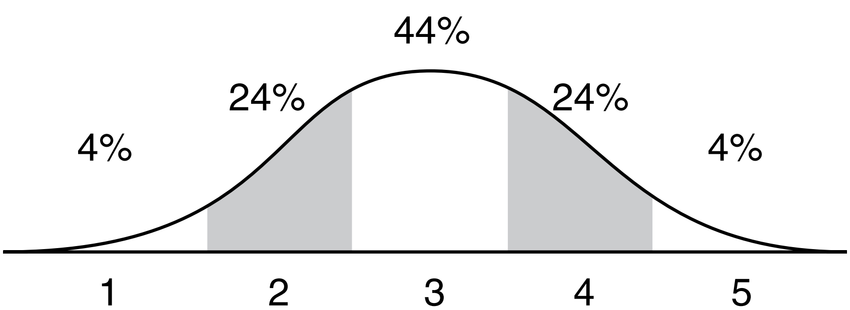


Figure 9. Normal Probability Distribution. This curve represents the normal probability distribution of human performance, and the five scoring categories represent equal intervals based on the variability of scores.

Admittedly a 5-point rating scale does not provide as fine a discrimination as one would desire, but evaluators will find it difficult enough to pick the best and worst 4% and the next best and worst 24% according to the distribution shown in Figure 9.

Once the WOMBAT-CS testing and the difficult task of rating candidates are completed, keep the results confidential until the statistical comparison is finished. If you desire you can release all the figures later, normally with the exception of the identities of the candidates.

To do the statistical tests, refer to your spreadsheet Functions manual and calculate the Pearson coefficient of correlation between the two sets of scores, using the WOMBAT-CS scores on one side and the 5, 4, 3, 2, 1 ratings on the other side. Feel free to contact Aero Innovation for support in your data analysis. Make sure that your criterion-based rating procedures closely followed the ones outlined above before you draw any conclusions about the predictive value of WOMBAT-CS, or of any other selection tests you may want to include.

What If I Test a Candidate More Than Once?

According to the present WOMBAT-CS users, it appears that once a candidate has reached his/her asymptotic performance, typically at mid-time during the test, there is little that a testee can do to improve his or her rate of scoring (Figure 10). Data typically show a constant, flat learning curve after the first 30 to 40 minutes of the first test.

A study at George Mason University near Washington, D.C. (Bruce 1994) using WOMBAT-CS, showed, however, a small increase of performance on the order of 6% of the overall score per

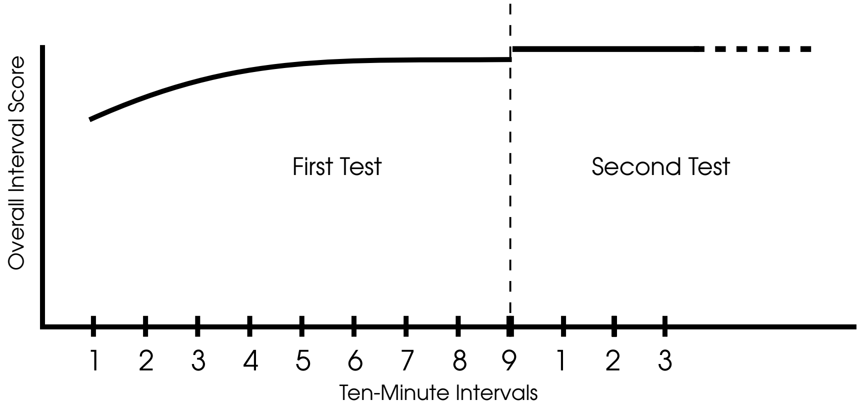


Figure 10. A Typical Two-Tests Group Learning Curve. A typical WOMBAT-CS group learning curve during a first administration of the test followed by the first 30 minutes of a retest a day or two later.

interval between the first and second administration. The amount of the performance increase, known as a "reminiscence effect," is generally attributed to the testee's thinking about strategy and mental rehearsal during the time between the two tests. Despite the reminiscence effect, Bruce demonstrated a correlation of 0.88 between the first test's ranking and the second test's ranking. This indicates that if a whole group of candidates were tested twice, they would keep nearly the same relative ranking at the outcome of the second test.

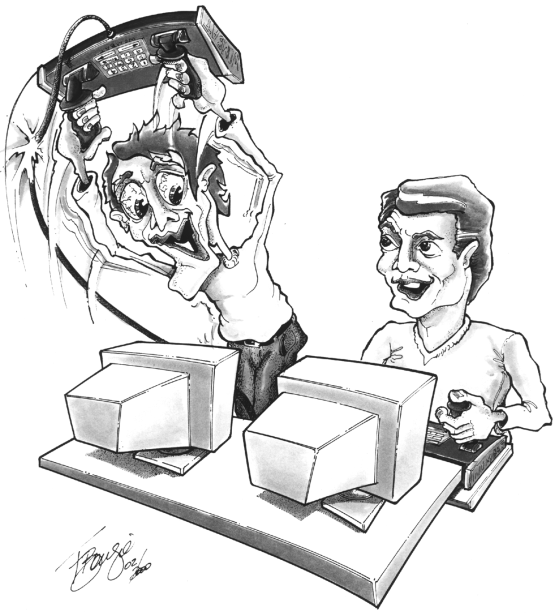
In 1999, during a pilot-fatigue experiment conducted by Dr. Patricia Leduc, the US Army Aeromedical Research Laboratory in Ft Rucker, Alabama, administered 9 consecutive 30-minute WOMBAT-CS sessions on elite Apache helicopter pilots and found no evidence of improvement beyond the first administration.

In your own organization, if you are particularly concerned about testees' requests for additional testing sessions, or if you believe some testees have received pretest training using a WOMBAT-CS system other than yours, just have everybody retested for 30 minutes a day or two later, and use those scores to rank the testees. This process can be aided by using two different WOMBAT.CFG files (possibly in two different subdirectories), the first governing a 90-minute test and the second specifying a 30-minute partial retest.

When testing everybody twice, you will short-circuit any attempt by testees to trick the system by training themselves on WOMBAT-CS prior to the screening process. If pretraining is not a potential factor in your organization, you can probably limit the administration frequency to once per year, thereby virtually eliminating any past-exposure advantage.

INTRODUCTION TO DUOWOMBAT-CS

9



ENHANCING AND PREDICTING TEAM PERFORMANCE

The solo WOMBAT-CS Situational Awareness and Stress Tolerance Test was designed to assess the inherent aptitude of individuals to operate complex systems without regard to their interactions with other individuals in a team or crew relationship. The latter situation calls for additional personal attributes, primarily social in nature but with a cognitive component, that have gained the attention of airline management and government regulators, leading to worldwide formal training in Crew Resource Management (CRM).

Although certain so-called personality tests are believed by some to reflect traits conducive to effective and harmonious interactions with other team or crew members, until recently there was no test, other than flight simulator exercises, specifically designed to call for the working exercise of those traits. As the WOMBAT test came into use by airlines and air and surface traffic control agencies, it soon became apparent that the higher-order cognitive demands it imposes on individuals could be extended to encompass the **social aspects of team performance**. To measure how well crew resources are managed, the solo WOMBAT-CS was expanded into the DuoWOMBAT Crew Resource Management Test.

DuoWOMBAT-CS

DuoWOMBAT-CS is a software program that runs on two WOMBAT-CS stations linked by a special cable. It challenges a pair's ability to work as team member managing a complex system. The program requires teammates to share various tasks, making sure that each member works on every task frequently.

In DuoWOMBAT, teammates work together; they must cooperate, not compete. To perform well as a team, both members must maintain a high degree of awareness of the total situation, including their teammate's performance as well as their own to manage this complex exercise effectively. High scores for team performance depend on how well teammates perform individual and duet tasks but even more on making good decisions as to what tasks each player should be working on at any given moment during the exercise.

DuoWOMBAT-CS can be either a testing or a training device. As a test, DuoWOMBAT-CS is used to evaluate a team's combined performance relative to the sum of the individual performance levels of the team members. Depending on the scenario designed by the supervisor, this may require each team member to be tested during solo phases for a few minutes before, between, and after two longer sessions of team performance, as shown in Figure 11.

Duo phases include duet versions of the primary tracking task and of each of the three secondary bonus tasks along with other features that require highly efficient task sharing.

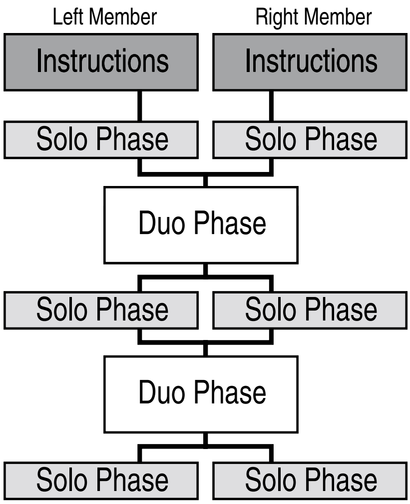


Figure 11. Typical DuoWOMBAT Test Scenario. This figure represents a typical test scenario named STD_TEST.SPT. Here, each team member goes through the timed instructions period separately then begins the sequence with a solo phase of 10 minutes. This is followed by a duo phase of 30 minutes, then another solo phase and so on. The alternation serves to establish a baseline for team member to identify the expected relative contribution of each to the combined team score. Any combination of solo, duo, instruction periods, and breaks can be selected by the supervisor in the custom-made scripts.

The 90-minute test shown in Figure 11 consists of two 30-minute phases of duo performance sandwiched between three 10-minute solo phases (10-30-10-30-10). The three solo phases provide a learning curve for each individual to serve as a basis against which the team's CRM performance is evaluated.

When Duo is used as a team-training device, the supervisor might create a script calling only for a sequence of Duo phases and breaks. Such sequences may include scheduled breaks for briefing/debriefing purposes (Figure 12). The supervisor monitors the training session and intervenes when needed.

The same configuration is also used within CRM classrooms as a virtual yet demanding cockpit-like environment, allowing demonstration and practise of learned CRM skills before a group of trainees. Objective evaluation of CRM training or periodic CRM assessment is also possible as

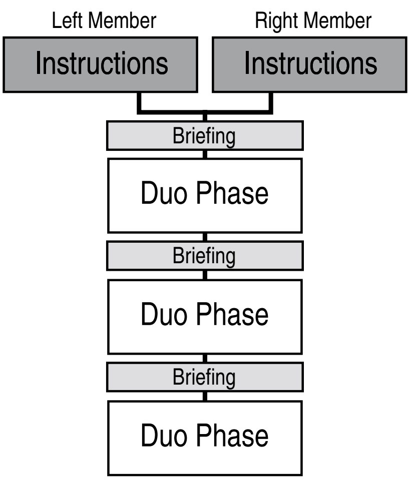
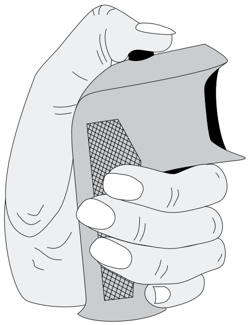


Figure 12. Typical CRM Training Scenario. This figure represents a typical Duo-only training scenario named STD_TNIG.SPT as delivered with DuoWOMBAT-CS.

change in the individual crew member's behavior will result in altered performance on the DuoWOMBAT test (beyond that attributable solely to taking and retaking the solo WOMBAT-CS test). Conversely, continued practice on the DuoWOMBAT would be expected to develop team behavioral attitudes and strategies that would readily transfer to the operational situation.

VIEWING THE DUO TRACKING TASK

During Duo phases, the **left**-hand Tracking Task appears only on the display of the teammate who presses and holds the **left**-hand stick's thumb switch. Similarly, the **right**-hand Tracking Task is only presented on the display of the teammate who presses and holds the **right**-hand stick's thumb switch. However, only one teammate at a time can call up each of the Tracking Tasks. Whenever both teammates attempt to view one of the Tracking Tasks by simultaneously pressing their corresponding thumb switches, that task is not shown on either display and will remain invisible until one of the two teammates releases a thumb switch.



Pressing and Holding the Thumb Switch

The situation just described is called a viewing conflict, and until the conflict is resolved, the Tracking Performance for that task will be zero. Working out effective procedures for sharing the Tracking Tasks between teammates will help avoid costly periods of viewing conflict.

Controlling the Duo Tracking Task

Although only one teammate can view each of the Tracking Tasks at any given time during Duo phases, both teammates can control the cursors then. The four joysticks are active whether or not a Tracking Task is visible on a given teammate's display. Consequently, just as there is the potential for viewing conflict, there is also the potential for control conflict with teammates fighting over the control of the cursors. Teammates must agree on how to share

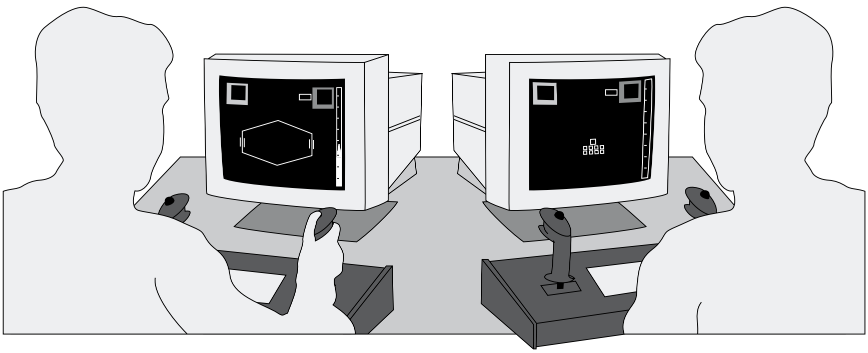


Figure 13. Controlling the Duo Tracking Task. Throughout the DuoWOMBAT exercise, teammates sit side-by-side in front of the two WOMBAT displays and consoles. Task sharing is a big part of a successful DuoWOMBAT performance. To avoid fighting over the tracking controls, teammates must establish efficient communication procedures, keep assessing their progress, and use all their team's available resources to maximize the combined score.

the Tracking Task to avoid interfering with each other. They have to use good team resource management to achieve the optimum combined team score.

The Duet Bonus Tasks

Chapter 3 described the Solo Bonus Tasks of DuoWOMBAT-CS. The Duet versions of these tasks, found in DuoWOMBAT, are similar to their solo versions but require the participation of both teammates for maximum performance scores.

The **Duet Figure-Rotation Task** shows one 3-D figure on each display. The teammate sitting on the left-hand side controls the figure that would appear on the left side of a solo WOMBAT display. Similarly, the teammate on the right controls the figure that would appear on the right side of a solo WOMBAT display (Figure 14). Either teammate can answer the problem; however, only the first response will be accepted by the program and scored on the side where it was made. Teammates must observe the current Bonus Worths on each display to decide which will earn more points for the team with a correct answer.

The **Duet Quadrant-Location Task** displays identical numbers in the four quadrants to each teammate. Either teammate can cancel numbers and earn points, but close observation of the Bonus Worth and Bonus Performance indicators will allow teammates to decide who shold cancel which numbers to maximize the team score.

The **Duet Digit-Canceling Task** will display the same sequence of digits to each teammate, and either can respond. Again, close observation of the Bonus Worth and Bonus Performance indicators will allow teammates to decide who shold cancel which numbers to maximize the team score.

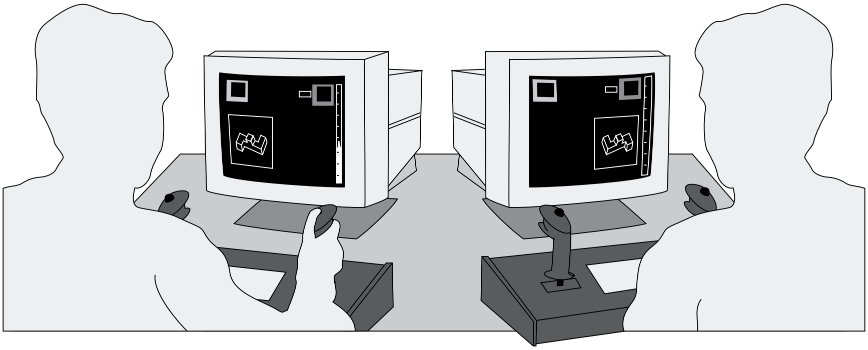


Figure 14. Duet Figure-Rotation Task. The two teammates above have agreed on doing a Duet Figure-Rotation Task. The left teammate controls the left-hand 3-D figure while the right teammate controls the right-hand 3-D figure. Either teammate can respond, but the program will accept only one answer. The sooner a correct answer is given, the sooner additional problems can be called up and solved. To maximize the combined team score, teammates must keep an eye on the changing Bonus Worths and determine who can earn more points by making correct responses.

CONFIGURING DUOWOMBAT-CS

10

DuoWOMBAT-CS was created with the idea that test supervisors and CRM facilitators would want to adapt the sequence of events to suit their specific requirements to assess, teach, or demonstrate effective team behavior. The result is a DuoWOMBAT totally scriptable and quite flexible but slightly more complex to set up than the solo WOMBAT software.

This chapter is intended to guide the operator in configuring DuoWOMBAT to control where and how the data will be stored and to create custom-made scripts. The following chapter will describe how to run DuoWOMBAT. In the next edition of this book, we will describe how to retrieve and read the data produced by DuoWOMBAT. Visit Aero Innovation's Web site to download updates of this book in PDF format.

DUO'S WOMBAT.CFG FILE

Locate the file named **WOMBAT.CFG** in the **Duo-CS.V15** subdirectory. This text file lists important parameters controlling a number of functions. The file delivered with Version 1.5 is shown in Figure 16. **WOMBAT.CFG** is a user-modifiable text file. You can use your favorite word processing package (but be careful not to add any formatting codes to the text) or a simpler application such as the DOS Editor to open and modify the contents of a text file. For example, at the DOS prompt, type:

EDIT WOMBAT.CFG <Enter>

Figure 15 shows what you can expect if you open the **WOMBAT.CFG** file. Each parameter is self-explanatory. If you collect WOMBAT data on more than one WOMBAT station, there is a question about where you will maintain a single archive of all the scores files. **DuoWOMBAT-CS's embedded safety features do not insure that duplicate names will not be on some other DuoWOMBAT station**. Consequently copying all scores together from different stations could result in loss of some scores files with duplicate names. For this reason we suggest that you use a unique scores subdirectory name on each of your WOMBAT-CS stations. Then copying each subdirectory to the single archive will keep the files from different stations from ever mingling.

```
* See the manual for advice on changing the parameters in this file *
562 The code for a standard VGA display (see README for others)
1 is the COM Port in this computer linked to the other computer (1 to 4)
RESULTS.DIR is the name of the scores subdirectory
```

Figure 15. Duo's WOMBAT.CFG File as Delivered.

Duo Scripts

The different phases of DuoWOMBAT are controlled and sequenced by the supervisor via custom-made scripts (or small programs). Each script controls which language will be shown on the WOMBAT displays during the entire session, how the data will be stored on the hard disk, how long the different phases will last, and in what order they will appear.

Like for the WOMBAT.CFG file, script files are user-modifiable text files. The files are stored inside the SCRIPTS.DIR subdirectory within the Duo-CS.V15 directory (Figure 16). All script files have a name ending with .SPT. Both DuoWOMBAT computers can store a number of scripts but only one script can run at a time. A menu of available scripts is shown on both displays following the successful use of the serial port specified in WOMBAT.CFG to communicate with the other computer. The operator must designate which computer will be "scriptor" by choosing the desired script. The other computer will receive its orders from the scriptor throughout the session.

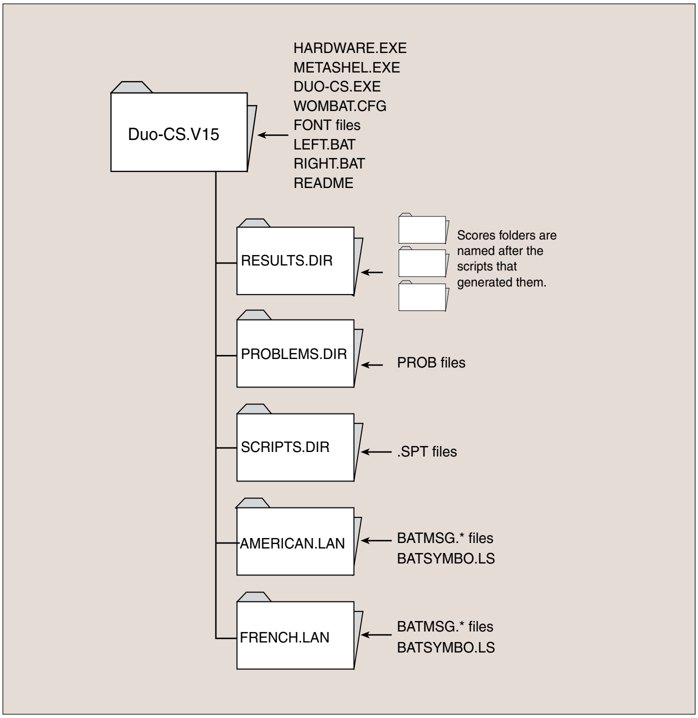


Figure 16. DuoWOMBAT-CS File Structure as Delivered. This figure represents the Duo-CS.V15 subdirectory structure and the enclosed files as delivered. RESULTS.DIR is the default name for the scores subdirectory from WOMBAT.CFG where all scores and composite scores files are stored. Scripts files are stored inside the SCRIPTS.DIR subdirectory and must end with .SPT to be recognized as scripts by DuoWOMBAT-CS. The subdirectories of the scores subdirectory (RESULTS.DIR bu default) are named for each script that is used to write data on that computer with the .SPT extension replaced by .DIR.

Creating a New Script

The easiest way to create a new script is to copy an existing script and modify the copy. The process of copying and editing a script is similar to the process of translating files described in Chapter 7. Figure 16 shows where the script files are stored on the DuoWOMBAT computers. Figure 11 shows a typical test script as delivered with DuoWOMBAT Version 1.5. This script is similar to the phases represented in Figure 17. It is recommended that you don't

```
AMERICAN.LAN is the name of the language directory
COMPOSIT is the prefix name for all the composite-scores files
RESEARCH.TXT is the research data file name
Bn creates a break
n is absent or not a number: gives an unlimited break
n < 0 gives an unlimited break
n from 0 to 127 sets the length of the break in minutes
n > 127 gives a 127 minute break
Dn creates a duo phase (see below for n)
In creates an instruction phase (see below for n)
Sn creates a solo phase (see below for n)
n is absent or not a number: gives a 1 minute phase
n < 0 gives a -1 minute phase
n from 0 to 127 sets the length of the phase in minutes
n > 127 sets a 127 minute phase
(** start of script
I60
B
S10
B1
D10
D10
D10
B1
S10
B1
D10
D10
D10
B1
S10
**) end of script
Anything written after the line above is ignored.
```

Figure 17. A Standard Test Script as Delivered. This figure shows the STD_TEST.SPT file as delivered. It is found inside the SCRIPTS.DIR subdirectory of DuoWOMBAT-CS. The script above is a typical test script that calls for an instructions period limited to 60 minutes followed by an unlimited break waiting for a user input before launching the first 10-minute solo phase. Short breaks separate duo and solo phases of different lenghts until the end of the script marked by the sign ***)* at the begining of the line.

modify the STANDARD.SPT file but copy it at will and modify the copies to suit your specific needs.

Any text editor can be used to modify the contents of a script file. You must make sure, however, not to insert formatting characters that will not be read by DuoWOMBAT.

To create a new script:

1. Choose one of the DuoWOMBAT computers for the script location.
2. Copy an existing script and rename the copy. The script name must comply with MS DOS format (8 characters maximum) and must end with the suffix .SPT.
   Example: **copy standard.spt new.spt**
   The above DOS command will create a copy of "standard.spt" and name it "new.spt".
3. Edit the copy with a text editor. Your modifications must be located below the line:

   (start of script**

   and above the line:

   ****) end of script**

   for the computer program to be able to read your script commands and execute them. You will use a special scripting language as described below.

INSTRUCTIONS PERIOD

Instructions periods are used by the teammates to learn and practice the various tasks involved in all phases of DuoWOMBAT. To schedule an instructions period, insert a script line with the character "I" at the beginning.

An instructions period is always time limited but teammates may terminate a period at any time. The time limit for an instructions period must be defined if you want it to be longer than 1 minute. Define the time limit in minutes by writing an integer after the "I." For example, "I60" means the instructions period will be limited to a maximum of 60 minutes. The maximum allowable duration is 127 minutes. The default (and minimum) duration is 1 minute.

The time the candidate actually spends in each of the instructions periods called for in the script will be summarized in separate columns of a spreadsheet file named with the prefix from the second line of the script or the default COMPOSIT with a .STO extension. This spreadsheet file and other similar files will be located in the subdirectory named from the script name.

Solo Phase

Solo phases are periods during which the two teammates work separately on their respective WOMBAT consoles at the same time. To schedule a solo phase, insert a line with the character "S" at the begining of the line.

Solo phases are always time limited. The maximum scriptable time for solo phases is 127 minutes. The default (and minimum) scriptable time is 1 minute. Specify the time with an integer after the "S."

Data for each solo phase in the script will be written to a composite spreadsheet file named with the prefix from the second line of the script or the default COMPOSIT and the extension .S*n* in the subdirectory named from the script name. The *n* extension will be a 1 or 2 digit number giving the sequential position of the solo phase in the script (or any instructions period). Then a composit spreadsheet file named with the prefix from the second line of the script or the default COMPOSIT and with extension .STO will be written to the same subdirectory with totals of all solo phases.

Duo Phase

Duo phases are periods of work for both teammates as a team in full interection. To schedule a duo phase, insert a line with the character "D" at the begining of the line.

Duo phases are always time limited. The maximum scriptable time for duo phases is 127 minutes. The default (and minimum) scriptable time is 1 minute. Specify the time with an integer after the "D."

Data for each duo phase in the script will be written to a composite spreadsheet file named with the prefix from the second line of the script or the default COMPOSIT and the extension .D*n* in the subdirectory named from the script name. The *n* extension will be a 1 or 2 digit number giving the sequential position of the duo phase in the script. Then a composit spreadsheet file named with the prefix from the second line of the script or the default COMPOSIT and with extension .DTO will be written to the same subdirectory with totals of all duo phases.

BREAK (OR PAUSE)

A break is a halt in the execution of DuoWOMBAT giving the teammates a chance to rest, discuss their strategy, or receive advice from training personnel. To schedule a break anywhere in the script, insert a line with the character "B" at the beginning of the line.

Unlike the other phases, breaks are not always time limited, except that the maximum scriptable time for breaks is 127 minutes. The minimum scriptable time is 1 minute. The default duration is an unlimited break. Any break can be terminated before the time elapses wiht an input from either one of the teammates. Specify the time in minutes for the break with a positive integer after the "B" or leave blank or use a negative integer for an unlimited break.

Scripting Considerations

Operators are invited to modify and duplicate scripts at will. Here are a few considerations about scripting.

Repeating Phases

Consider breaking down a long period of work into several shorter phases. Each time a phase ends a "phase end" signal is exchanged between the computers and the current results from both computers are stored in several scores files. For example, if you plan to have 30 minutes of duo work, you can script three consecutive duo phases of 10 minutes. This sequence will produce three sets of duo scores in the scores files instead of a single set of scores. Operators used to running the solo WOMBAT-CS will notice the similarity of script phases used in this manner to score intervals. Although pointless, you can schedule consecutive breaks.

Teammates' Agreement

Only input from one teammate is required to terminate an instructions period or a break before it times out. Such an input throws both teammates into the next phase, whatever the level of readiness of the other teammate. This potential for conflict resulting from a failure of communication is intentional. However, the sudden end of an instructions period that reaches its time limit while both teammates are engaged in study and practice could be quite disruptive for their performance if a solo or duo phase follows immediately in the script. It is therefore recommended that a break period be inserted after an instructions period to prepare the teammates for the following work phase.

Unique Instructions Set

There is only one set of instructions. The set contains all the screen-pages of text and all the practice sessions for DuoWOMBAT thus convering all topics. Sequencing more than one instructions period into a single script will simply make the complete set of instructions available again for another limited time. A future version of DuoWOMBAT may discriminate between solo-oriented instructions and duo-oriented instruction so that they could be scrited separately.

Script Names, Scores Files

The DuoWOMBAT program uses the reference string entered by the test administrator to create a summary scores file. If the administrator does not specify a filename extension, by default the filename will bear the usual .SCR extension. Scores files are stored in the scores subdirectory specified in the WOMBAT.CFG file (RESULTS.DIR is the default).

DuoWOMBAT also generates composite scores files that are easily loaded into commercial spreadsheet programs. These composite scores files are generated by any instructions periods or solo or duo phases scheduled in a script using names determined by lines in the script. They are stored in the scores subdirectory, inside a subdirectory that uses the name of the script that created the files and a .DIR extension.

Running DuoWOMBAT-CS 11

Launching DuoWOMBAT-CS

We will store the DuoWOMBAT-CS program and all the necessary files in a subdirectory named after the version of the DuoWOMBAT-CS program current at the time of shipment. For example, Version 1.5 of DuoWOMBAT-CS will be stored on the hard disk of your computer in a directory named **Duo-CS.V15**.

Subsequent updates of the program should be stored in distinct directories to insure a smooth transfer from old versions to new ones, prior to deleting superseded versions.

To run DuoWOMBAT-CS switch to the subdirectory that contains the DuoWOMBAT-CS software. The batch commands **LEFT.BAT** or **RIGHT.BAT** supplied with your DuoWOMBAT software will load in sequence everything that is required for a DuoWOMBAT-CS session. On the left computer type:

LEFT <Enter>

On the right computer type:

RIGHT <Enter>

and you will have **HARDWARE**, **METAWINDOW** and **Duo-CS** in the appropriate sequential order.

Reference Strings and File Annotations

When DuoWOMBAT-CS is launched as a new start, the user is asked to enter a reference string on the computer that is the source for the script and file annotations **on both computers**. The reference string must be entered by the user for the program to be able to store the exercise results in one of the scores files. It can also allow the user to match a team of candidates with their results in a coded manner.

If the string you type contains a period "." then the string as you enter it will be used to name a DOS file. If there is no "." in the string, then **.SCR** (for **SC**o**R**e file) will be added to the end and used to name a DOS file. In both of these cases an error will be generated if the string is not a legal DOS name. It is recommended that you create and maintain a consistent system for determining a unique reference string assigned to each team tested or trained on DuoWOMBAT.

The file annotations are optional and can be any message up to 30 characters long. The information is only copied by the program into the final results file for future reference. If you do not wish to enter a file annotation, just press **<Enter>**.

If DuoWOMBAT-CS detects another file in the scores subdirectory named in WOMBAT.CFG (the current scores subdirectory) with the same name as the one created from the reference string, you will be asked to decide whether to erase it or to go back and reenter a different reference string to avoid duplicating the file name. This check only guarantees that the current scores file will not overwrite any other scores file existing in the **current scores subdirectory**. If you decide to erase an old scores file at this point, the data collected and stored under that filename in the **composite spreadsheet data file** will remain, thus creating two records (or rows of numbers) with the same scores filename (see **Composite Spreadsheet Data File**). It is therefore good practice not to erase an old scores file and to select another reference string if prompted to do so.

It is highly recommended that you periodically archive (or backup) the score files.

Single Data-Storing Computer

A DuoWOMBAT session generates an impressive amount of data for further analysis. That data is stored in the computer that runs the script, in the results subdirectory as shown in Figure 18. If the desired script is present on both computers, the surpervisor can choose which computer will store the data for both teammates by choosing which computer will run the script.

The other computer will not store any data related to the current session but will send it all over the connection cable to the computer chosen to store it.

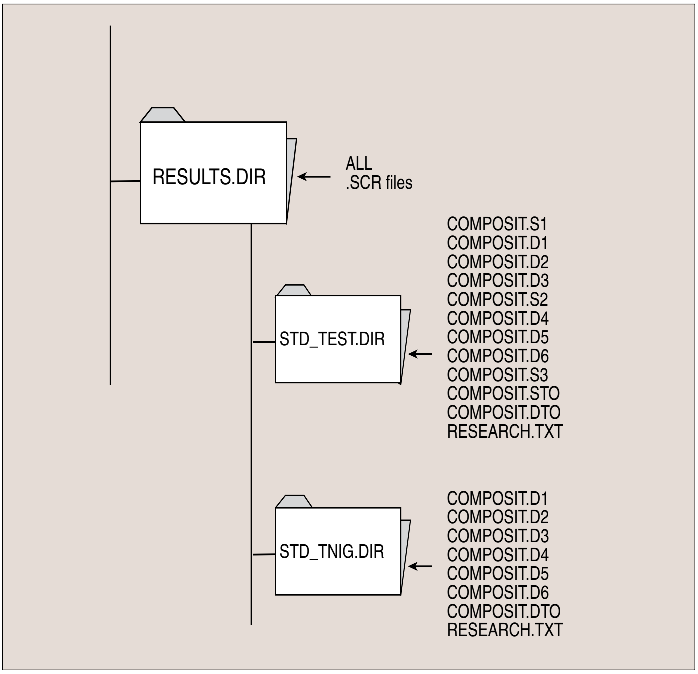


Figure 18. DuoWOMBAT-CS Scores Storage Structure as Delivered. This figure represents the Duo-CS.V15 subdirectory structure where all the scores are stored. RESULTS.DIR is the default name for the scores subdirectory. All *.SCR files are stored in this subdirectory along with folders named after the scripts that generated them. In the figure above, two scripts generated their respective folders. The first script was the standard test script STD_TEST.SPT described in Figure 11. The second script was the training script STD_TNIG.SPT described in Figure 12. These folders contain all the spreadsheet data files generated by DuoWOMBAT-CS.

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INTERFACE INSTALLATION ON ANOTHER COMPUTER

Appendix 1

This section of the manual is provided in case you have to install the WOMBAT-CS system in another computer.

SYSTEM REQUIREMENTS

The minimum configuration for WOMBAT-CS is a PC compatible system that includes a 486DX processor and 1 megabyte of RAM. The graphics system must be color VGA. Nowadays, WOMBAT-CS is delivered on fast Pentium PC Compatibles but this level of performance is far from being a requirement to run WOMBAT-CS.

INTERFACE INSTALLATION

The WOMBAT interface board occupies 5 locations in the Input/Output space from 300 (Hex) to 304 (Hex). Other boards in your system that conflict with this (such as modem, scanner, or sound cards), will need to be removed. If you do have to remove one or more cards from the PC Computer, make sure you also disable their drivers in the **CONFIG.SYS** or **AUTOEXEC.BAT** files.

The base address switches on the WOMBAT board have been set for these values, but you should check them before proceeding to a new installation. The correct dip settings are shown in Figure 19.

To install the WOMBAT interface board, proceed as follows:

1. Turn off the power to the computer and remove the cover.
2. Remove one of the rear cover plates and insert the board

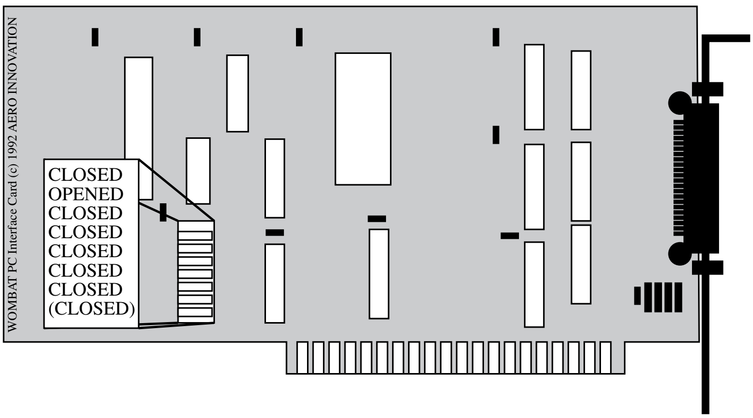


Figure 19. WOMBAT Interface Board. Base address switches on the WOMBAT board have been set for the values shown. You should check them before installation.

firmly into the connector on the mother board.
3. Refit the cover plate screw to hold the board in place.
4. Fit the cable into the socket on the interface board. Push it home firmly taking care not to bend any of the pins. The plug is polarized so that it can have only one position. Connect the other end to the socket on the WOMBAT console.
5. Arrange the control box on a table in a comfortable position and switch on the computer.

THE WOPPI

In 2001 a new device was introduced: The WOMBAT Parallel-Port Interface. The WoPPI allows the connection of up to two standard WOMBAT consoles to a single computer via its parallel port. This accessory, sold separately from Aero Innovation, is perfect for operating WOMBAT with laptop computers, whether using the laptop's own LCD monitor or a separate plug-in CRT monitor.

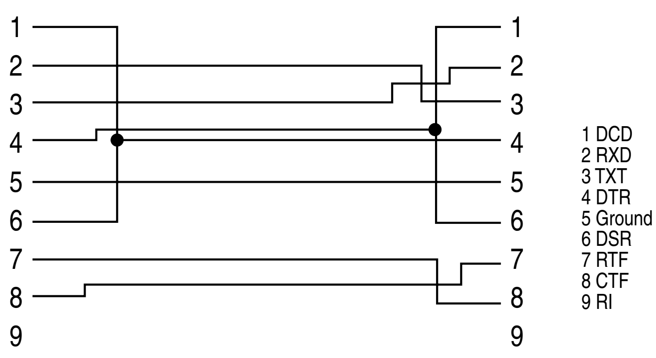
THE DUOWOMBAT CABLE

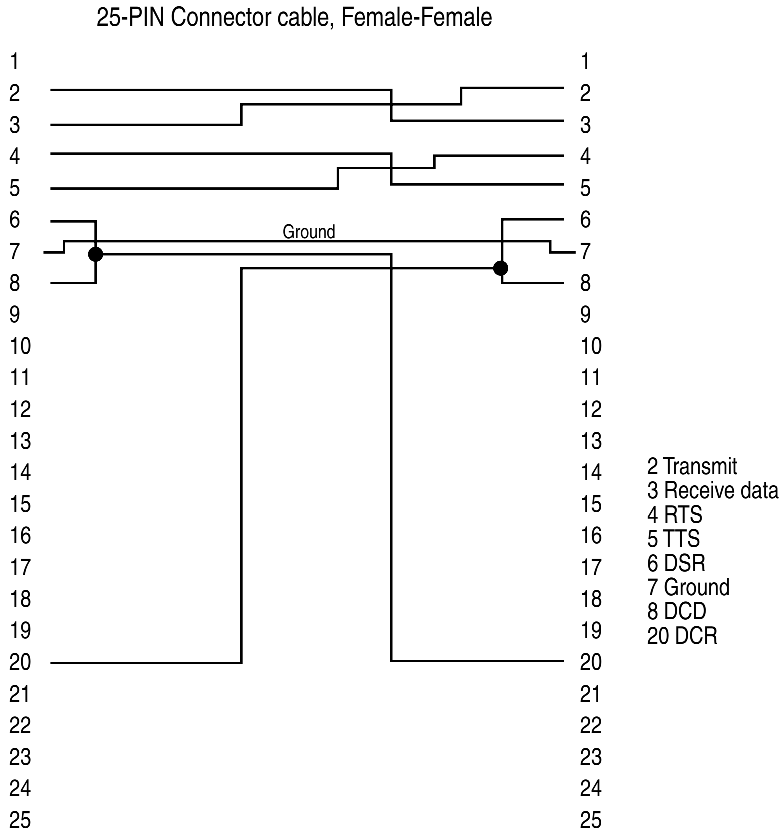
Appendix 2

CABLE CONFIGURATION

DuoWOMBAT-CS requires a special null-modem cable to link the two computers via their COM serial ports. The cable is normally supplied by Aero Innovation. Below is the configuration when DB-9 connectors are used and next page shows the configuration for DB-25 connectors.

9-PIN Connector cable, Female-Female




25-PIN Connector cable, Female-Female
Ground
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
2 Transmit
3 Receive data
4 RTS
5 TTS
6 DSR
7 Ground
8 DCD
20 DCR

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