DIVISION 21 MEMBERS

Who Made Distinguished Contributions to Engineering Psychology

EDITED BY

Henry L. Taylor

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Introduction

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John J. O'Hare proposed in 1987 establishing an ad hoc Committee on Monographs of Distinguished Division 21 members. The Executive Committee, at its August 1987 meeting, approved the proposal and requested that he chair the committee. The criteria for the selection of candidates for a monograph were that a person be a past member of Division 21, deceased, and distinguished for his or her contribution to engineering psychology.

The criteria for selection of authors to write about the candidates were familiarity with the candidate, willingness to allow the APA to hold copyright of materials, agreement that all royalties for sale of publication would be assigned to Division 21, and agreement that each essay would be completed in time to make a Division 21 contribution to the celebration of the APA's centenary.

The following announcement was published in the fall1988 issue of the Division 21 *Newsletter,* 16(1):

Monographs of Distinguished Members

> As a contribution to the celebration of APA's centenary in 1992, Division 21 would like to prepare monographs on deceased members of our Division who have made distinguished contributions to the field of applied experimental psychology or engineering psychology. Sugges- tions of the membership are solicited regarding the past members who should be honored and information or materials on those members would be welcomed. Self-nominations of biographers are also encour- aged.
>
> Some names that have been proposed include: George Briggs, Jack Dunlap, Jerome Ely, Paul Fitts, Ross McFarland, Arthur Melton, Ralph Queal, Frank Taylor, and Alex Williams.
>
> A few individuals have already volunteered to prepare monographs for several of the above nominees. The final selection of biographers would be based in part on familiarity with the candidate, ability to com-

plete the work within a stated time-frame, willingness to grant the APA copyright of the materials, and agreement that all royalties from sale of the monograph would be assigned to Division 21.

You are invited to submit your nominations to the Chair of the ad hoc Committee on Monographs: Dr. John J. O'Hare, Office of Naval Research, Code 1142PS, 800 N. Quincy St., Arlington, VA 22217-5000.

Biographers were asked to provide a brief treatment so that the total number of pages for the monograph would be about 150, or about 15 pages per nominee; emphasize the technical contributions of the individual rather than personal details of their lives; and show the future directions possible from the technical achievements of each individual, that is, the relevance or enduring value of the individual's contributions.

At the 1991 midyear meeting of the Executive Committee of Division 21, the following list of eminent deceased members was approved for inclusion in a biographical monograph that would constitute the Division's contribution to the APA centennial year. The list of biographer and biographee was confirmed as final in a June 13, 1991, letter from John J. O'Hare to Robert S. Kennedy, president of Division 21.

Biographer	*Nominee*
Randall M. Chambers	Arthur Melton
Richard W. Pew	Paul Fitts
Stanley N. Roscoe	Alexander Williams
Richard E. Christ	Warren Teichner
William C. Howell	George Briggs
Malcolm L. Ritchie	Ross McFarland
Jesse Orlansky	Jack Dunlap
Martin A Tolcott	Jerome Ely
John J. O'Hare	Franklin V Taylor

At the 1992 annual meeting, the Executive Committee of Division 21 accepted the recommendation that the proposed authors for biographies of A Melton and W. Teichner be excused and that replacement authors be pursued. Later the author of the biography of Franklin V Taylor withdrew.

Copies of the manuscripts from W. C. Howell (George Briggs); Jesse Orlansky (Jack Dunlap); R E. Pew (Paul Fitts); M. L. Ritchie (Ross McFarland); S. N. Roscoe (Alexander Williams); and M. E. Tolcott (Jerome Ely) were forwarded to Ralph Dusek, who forwarded the manuscripts on June 28, 1993 to Tom Eggemeier, president, of Division 21.

In a letter of July 23, 1993, to Tom Eggemeier, John O'Hare indicated that he could not continue as editor of the monograph. At its meeting in August 1993, the Executive Committee appointed me to serve as editor of the existing contributions to the monograph; later a decision was made to include the text of a paper, “Roots and Rooters” presented by Earl A. Alluisi during Division 21's celebration of the American Psychological Association centenary. The published monograph will be distributed to the Division 21 membership as a benefit of membership.

The Executive Committee and I thank the contributors to the monograph for providing their individual contributions and Mary Jane Alluisi for permitting me to include Earl's manuscript in the monograph. Finally, I thank Diana Christenson for assistance with retyping manuscripts and Mary Giles for copy editing assistance.

APA Division 21: Roots and Rooters

EARL A. ALLUISI

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The United States military establishment has supported research (broadly defined) from the beginnings of our nation. From the American Revolution to the Civil War, the Army and Navy conducted or sponsored expeditions for explorations and territorial discovery.

After the Civil War, and until the expansion of military efforts during World War I, the Navy and War departments recognized the need for research to address areas of benefit to the Armed Services, and they established the Army Medical Laboratory, the Naval Observatory, and the Naval Radiotelegraphic Laboratory. They backed Langley's research on the potential military uses of the "flying machine."

During the period of U.S. military hibernation between the two world wars, military research and development (R&D) was not abandoned completely. The Naval Research Laboratory, the Navy Office of Research and Inventions, and the Army's Ordnance Laboratories were established. R&D in aviation medicine (including some aspects of military aviation psychology) was also supported, and the Manhattan Project was initiated to create the first atomic bomb.

Military Psychology in World War I, 1917-1921

The roots seem to have begun on April 6, 1917, the day the United States entered World War I, and the date that can also be taken to mark the beginning of U. S. military psychology. As Uhlaner (1968) summarizes the events crucial to the involvement of psychology in the war effort,

> Military psychology, in fact, got its start on April6, 1917. On that day, a meeting of experimental psychologists under the auspices of the American Psychological Association was being held in Emerson Hall of Harvard University. In the midst of this meeting, a messenger burst into the session chambers with the grave announcement that our country had just entered the conflict. Then and there, Dr. [Robert M.] Yerkes and a small group of forward looking psychologists put in motion most energetically a series of actions, including letters that same day to members of the Council of the American Psychological Association and to theNational Research Council outlining what psychology could do for the national defense effort.
> In the spring of 1917, the first United States military psychological effort had its inception under Captain Yerkes of the Sanitary Corps, starting with the problem of enlisted classification. (vi-vii)

Presented at the annual meeting of the American Psychological Association, Washington, D.C., August 1992.

Earl Alluisi died on August 14, 1993.

Psychology mobilized quite rapidly. On Apri121-22, 1917, the APA Council voted that APA president "be instructed to appointment committees from the membership of the American Psychological Association to render to the Government of the United States all possible assistance in connection with psychological problems arising in the military emergency" (Yerkes, 1921, p. 8).

Between this beginning in the spring of 1917 and the end of January 1919, American psychologists working with and in the U.S. Army's psychological services:

> Developed two group mental tests based partly on the earlier work of Otis-the Army Alpha (for the classification of English-language literates) and the Army Beta (for illiterates)-and determined their reliabilities (r's = .95); their validities (e.g., with the Stanford-Binet, Alpha r = .80 to .90, Beta r = .73); and their intercorrelations (Alpha with Beta, r = .80; see Anon., 1919, p. 225);
> Organized mental testing ("psychological examinations") for personnel classification in 35 army training camps;
> Trained 100 officers and more than 300 enlisted men as examiners;
> Psychologically examined (tested) a total of 1,726,966 men, including more than 42,000 officers; and
> Assisted in the work of the development battalion's work that resulted in the qualification for military assignment of more than 50% of the nearly 230,000 men who were assigned to those units and provided treatment, physical training, or instruction for varying periods of time in them.

These reflect some of the major contributions of psychologists in World War I - the development of mental tests for the selection, classification, and assignment of military personnel. There were other notable psychological activities and contributions as well. For example, research on psychological problems of aviation officially came under the direction of the Aviation Medical Research Board, a branch of the

Air Medical Service that "took charge" of all medical, physiological, and psychological problems relating to the behavior of flyers (Henderson, 1918).

Yerkes gives an extended report on the range of activities. He identifies not only the 13 committees that were "active for varying periods during the military emergency" but also four areas of special work of individual members of the Psychology Committee or its subcommittees (1919, pp. 84-85). The 13 committees examined psychological literature; examining; aviation; special aptitudes; recreation; vision; military trainlng and discipline; incapacity; emotional stability, fear, and self-control; propaganda; acoustic problems; tests for deception; and adaptation of psychological instruction *to* military educational needs. The four areas of special work were scouts and observers; the gas mask; the Students' Army Training Corps; and special problems in learning, methods of instruction, and of selecting for special tasks.

The work of the Committee on Psychological Problems of Aviation, Including Examination of Aviation Recruits is especially relevant *to* engineering psychology's early roots. The committee was authorized by the APA Council and also became a subcommittee of the National Research Council. It was initially chaired by Harold E. Burtt and included as members W. R. Miles and L. T. Troland, and, in the words of Yerkes, it progressed as follows:

> In the summer of 1917 the committee was reorganized. Burtt resigned and George M. Stratton who had been working independently on tests for aviators at Rockwell Field, San Diego, was appointed chairman. Edward L. Thorndike was chosen as executive secretary, and John B. Watson, Warner Brown, Francis Maxfield, and H. D. McComas were added to the membership.
>
> From August 4, 1918, Thorndike served as chairman of the subcommittee on aviation. From the records of over two thousand flyers, Thorndike determined the relation between actual success in the work of a military aviator over the lines[,] and age, social status, intellectual ability, business achievement, athletic ability, and many other characteristics. (1919, pp. 96, 99)

Work was also accomplished on topics other than selection and classification; for example, Yerkes reports that:

> To Major John B. Watson was assigned, in the summer of 1917, the task of organizing methods, other than medical, to be used by the examining boards for the selection of personnel. Watson also assisted in organizing a group of research psychologists to collaborate with physiologists and medical officers in the study of aviational problems at the Bureau of Mines, Washington.
>
> Special mention should be made of the Psychology Section of the Medical Research Laboratory at Hazelhurst Field, Mineola, Long Island, which developed from the work inaugurated in Washington by Watson and his associates. At this station, Major Knight Dunlap was primarily responsible for the development of a series of psychological tests to assist in determining the ability of candidates for the aviation service to withstand the effects of high altitudes.
>
> In general the method employed called for the performance by the subject of a group of continuous tasks involving coordinated reactions during the gradual decrease of oxygen supply. (1919, pp. 97-98)

Among the early reports of results on the "various ways in which the effects of coordination and attention are manifested in different reactors," Dunlap (1918, p. 1393) suggests that a general methodology involving continuous tasks like those he used in his oxygen-deprivation experiments could be used in studies "of the problems of drug and fatigue action" (p. 1392)--clearly, a prediction of the utility of performance measures for the psychopharmaceutical dose-effects curves that were to follow decades later.

Among the committee's other research efforts in which one can sense the early roots of engineering psychology are some examples that Yerkes reported:

> H. L. Eno and O. V. Fry developed apparatus for measuring the aviator's ability to point his plane quickly and accurately in a desired direction, as at an enemy plane.
>
> Major Watson was sent to Europe to gather statistics on the qualities essential to success as a military aviator.
>
> Dr. Parsons of the Navy received help from the committee in giving tests to every candidate for flying status in the naval air service. Parsons' study of the relation of the duration of nystagmus after rotation to flying ability yielded negative results, which are corroborative of Thorndike's findings, and supported by Dodge's analysis of nystagmus reactions. (1919, p. 99)

Early in the war, Raymond Dodge, later Lieutenant Commander Dodge, was assigned the problem of devising a test for the selection of naval gun-pointers (Yerkes, 1919, pp. 106-124). In solving the selection problem, he constructed and demonstrated an instrument to test gun-pointers. The device gave a series of graphic records of the basic processes involved in training a gun on a moving target. When it was tested aboard two battleships, the best gun-pointers gave the best records, and the untrained recruits the worst. However, even though the testees had only five trials each, Dodge had observed learning curves in many cases. This led him to try to devise a suitable training device. In the process of doing so, Dodge constructed what must be counted among the earliest and most successful of comprehensive part-task trainers (man-:in-the-loop) simulation. According to Thorndike,

> He [Dodge] studied the task of the gun-trainer and pointer, the situations and responses involved, the methods of testing their ability then in use, the men from whom selections would be made, and the practical conditions which any system of selection for this work must meet. He had the problem of imitating the apparent movements of the target which are caused by the rolling and pitching of the gun-platforms as a distant object would appear to a gun-pointer on a destroyer, a battleship or an armed merchantman. He solved this by moving the imitation target through an 84-phase series of combined sine curves at variable speeds by a simple set of eccentrics, motor-run. He had the problem of imitating the essentials of the control of the gun by the gun-pointer and of recording in a fuller and more convenient form the exact nature of the gunner's reactions in picking up the target, in getting on the bullseye, in keeping on, in firing when he was on, and in following through. He solved these by a simple graphic record showing all these reactions on a single line that could be accurately measured, or roughly estimated.
>
> Subsequently he made an apparatus that could be used not only to test a prospective gun-pointer's ability, but also to train both gun-trainers and firing gun-pointers four at a time. The demand for these instruments has been so great that sixty have been built by the Navy for use at shore training stations. The success of this led to further similar work, especially on the problem of the listener, the lookout and the fire control party. (1919, pp. 57-58)

Dodge also began experimentation on the effects of gas-mask "tenancy" (or duration of wearing) of the standard-production mask. He served as the sole subject, but with multiple psychophysical types of performance and physiological measures. He reported:

> The most consistent and largest effect of gas-mask tenancy was decrease of visual acuity, an average of 20 per cent. Addition was slowed 7 per cent. Eye-reactions were longer by 9 per cent. Eye-movements were 7 per cent slower. In lesser degree the finger reactions, finger movements, and dynamometer strength tests were adversely affected, three, two, and one per cent, respectively.
>
> Of vastly greater importance than the fractional falling off in efficiency of the various processes was the effect of improperly made or improperly fitted head gear. Within one hour I had reached a degree of discomfort from an ill-fitting head gear where in spite of experimental interest in the task, in spite of patriotic sentiment, and all the scientific pride I could muster, I could stand the punishment no longer and simply took the mask off. The extreme military importance of such a condition of mind seems clear. A properly constructed and properly fitted mask can be worn almost indefinitely, after adaptation.
>
> *It was officially reported that our study and the recommendations that grew directly out of it were of substantial help in developing the modem mask.* (Yerkes, 1919, pp. 122-123; emphasis added)

Later :in the same paper, Yerkes reports that Major Knight Dunlap was assigned "to continue and extend the :investigations on tenancy of the gas mask initiated by Dodge" (p. 143), and that just before the end of the war "Dunlap had perfected a procedure for determining the effects of different types of masks on the efficiency of the wearer" (p. 143).

The preceding is certainly sufficient evidence to support the conclusion that the early roots of engineering psychology :in the United States go back at least as far as World War I. These successes joined those of mental testing for personnel classification and assignment, and for the selection of candidates for flying training and combat flying. But it is Thorndike (1919) who touches on what is probably the major contribution of the psychologists in World War I and a primary early root of U.S. engineering psychology: the application of the scientific method to the practical problems of the Army and Navy during time of war. These successes fostered the further development and growth of all branches of applied psychology. As Thorndike describes it, "The sciences dealing with human nature were brought to bear upon the problems forced upon America by the world war. Anthropology and psychology, economics and statistics, history, sociology and education, were put :in service to improve our use of manpower, just as the physical and biological sciences were put :in service to :increase, economize and mobilize the nation's physical resources" (p. 53).

United States Military Hibernation, 1921-1939

After World War I, the Army reverted to its prewar personnel proce- dures, reinstituting "what was in effect an apprenticeship system of selection and assignment" (Uhlaner, 1968, p. 9). But military psychol- ogy was not entirely eliminated from the Army, and aviation psychol- ogy especially was continued under the aegis of the medics.

The Army appo:inted the Aviation Medical Research Board :in 1917, and the board established the Air Service Medical Research Laboratory :in 1918 and the School for Flight Surgeons :in 1919. In November 1919, both were moved from Hazelhurst Field in Mineola, Long Island, to larger quarters at Mitchel Field, New York Then, in November 1922, both the school and the laboratory were combined into a single organization named the School of Aviation Medicine (SAM).

SAM was relocated in 1926 from Mitchel Field to Brooks Air Force Base, Texas, to be near the large cadet training center in San Antonio. Then, in 1931, SAM was moved along with the Air Corps Training Center to Randolph Air Force Base, Texas.

Aviation psychology played a supporting role at SAM-a role that emphasized the collection and analysis of performance data from pilots who were exposed (either in aircraft or in the laboratory) to the physical and physiological stresses studied.

In the meantime, the early roots of engineering psychology were spreading in the aviation psychology research of other medical or life sciences R&D groups. For example, the Physiological Research Unit of the Air Corps Materiel Division was established at Wright Field near Dayton, Ohio, in 1934, to provide medical engineering for the design and testing of equipment to protect pilots from the hazards of their flight environments.

The unit tended to focus on determining the natural limitations of flyers and on either developing support equipment to extend those capabilities or adapting the design of the aircraft being developed to conform to human limitations. It became known as the Aero Medical Research Unit during the late 1930s, and its studies of cabin pressuriza- tion, rapid decompression, oxygen supply systems, and related life support equipment greatly influenced the design and operation of many military aircraft used throughout World War II.

In his report on "Military Psychology in the United States of America" before the First International Symposium on Military Psychology, held during July 1957 in Brussels, Belgium, Arthur W. Melton slimmarized the "hibernation" era: "Between World War I and World War II, there was almost no interest of American psychologists in military problems, perhaps because there was almost no interest of the military in gaining the assistance of psychologists. Exceptions were the development of a new and improved Army General Classification Test by The Army Adjutant General and some research on psychomotor selection tests for aircraft pilots which was done under the aegis of The Surgeon General of the Army Air Corps. Then, with the clouds of World War II on the horizon, psychologists were recruited rapidly and in large numbers to do a great variety of research studies and technical applications for the benefit of military operations" (1957, p. 741).

Military Psychology in World War II, 1939-1945

Army

By August 1939, Army psychologists had constructed a new classification test that emphasized "trainability." The Army General Classification Test (AGCT), Form 1a, after standardization, was first used the next year, in October 1940. Uhlaner reports that "a second form was introduced in April 1941. Two additional forms, 1c and 1d, providing improved discrimination, placed 1a and 1b in October 1941. Nonlanguage tests for illiterates, mechanical and clerical tests, and trade tests were prepared. By the end of the war, AGCT in its various forms had been administered to over 9,000,000 men" (1968, p. 11).

During the period of World War II, 1939-1945, the Army's psychologists applied the AGCT and other tests to a large number of people-on the order of 13,000,000-in the selection, classification, assignment, and training of personnel in all the military services and in counseling separating veterans.

Psychologists also established the usefulness of clinical psychology in military medical and hospital settings, and by the end of July 1945, 250 clinical-psychology officers had been obtained to provide neuropsychiatric services in Army hospitals. Later, the employment of clinical psychologists was extended to Veterans Administration (VA) hospitals, thereby fostering greatly the acceptance, utilization, and growth in the United States of that area of applied psychology.

ARMY AIR FORCES

In the Army Air Forces (AAF), military aviation psychologists applied experimental psychology to aviation problems and developed entirely new fields of technology applications and research studies-human factors engineering and engineering psychology. Melton states that the largest single program in World War II, that of the Army Air Forces, "was organized under medical auspices" (1957, p. 741). That program was headed by John C. Flanagan.

According to Flanagan (1948, pp. 7 ff.), it was partly because of a shortage of flight surgeons that the chief of the Army Air Corps Medical Division recommended, in May 1941, that a Psychological Research Agency be established in the AAC Medical Division. The recommendation was approved on June 14, 1941, and a month later, on July 15, 1941, John C. Flanagan (then associate director of the Cooperative Test Service, American Council on Education) was commissioned a major in the Specialist Reserve branch of the Officers' Reserve Corps. He went to work the next day.

Four years later, at the end of June 1945, the AAF Aviation Psychology Program :included Colonels John Flanagan, Frank Geldard, J. P. Guilford, and Arthur W. Melton; about 200 other officers; 750 enlisted men; and 500 civilians, whose accomplishments are recorded :in the 19 volumes of the Army Air Forces, Aviation Psychology Program Research Reports published :in 1947 and 1948.

Their R&D on aircrew selection and classification had blossomed, especially after early 1942, when the Army shifted that responsibility from the surgeon general *to* the newly created AAF Flying Training Command. Their work led *to* the development of two examining procedures, both of which were outstanding successes from scientific as well as applied viewpoints: (1) a 150-item screening examination called the AAF Qualifying Examination, the use of which rejected from between a quarter and a half of the more than one million aircrew applicants; and (2) the Air-Crew Classification Test Battery consisting of 20 tests-six apparatus tests of coordination and speed of decision and 14 printed tests that measured :intellectual aptitude and abilities, perception and visualization, and temperament and motivation.

Performance was recorded :in terms of a nine-category standard score with a mean of 5.0 and standard deviation of about 2.0, called a *stanine.* Testees were assigned stanine scores for the various aircrew specialties based on weighted combinations of the results from various tests :in the battery. More than 600,000 men took this comprehensive battery of tests. The stanines were found *to* have high predictive value, especially for pilot and navigator training success, and *to* be correlated significantly with measures of success :in operational training and in combat.

The AAF Aviation Psychology Program was probably the taproot of eng:ineer:ing psychology or human factors engineering. Paul M. Fitts (1947b), generally regarded as a founder of the field, edited *Psychological Research on Equipment Design,* number 19 :in the series "Army Air Forces, Aviation Psychology Program Research Reports." In addition *to* that publication, the reports covered all aspects of the field, including programs on aviation psychology; classification programs; research problems and techniques; apparatus tests; printed classification tests; the AAF qualifying examination; motion picture testing; training for pilots, bombardiers, navigators, radar observers, flight engineers, and for flexible gunnery; AAF convalescent hospitals; operational training :in the Continental Air Forces; research :in the theaters of war; and records, analysis, and test procedures.

Thus, the progress of engineering psychology during World War II can be summarized as follows: During the early years, 1941-1944,

numerous eminent psychologists were brought :into the Army Air Forces *to* devise effective methods of aircrew selection and training. They succeeded in developing and implementing stanine scores, which were based on a batter of psychomotor and paper-and-pencil tests and used principally *to* select and classify candidates for pilot, navigator, and bombardier training.

During the later war years, 1944-1945, AAF psychologists emphasized criterion development, test validation, and training, with projects at Randolph, Mather, and Lowry Army air bases. Some psychologists from 1945 onward were engaged in the new area of "engineering psychology" or "human engineering" that Paul Fitts and his colleagues established :in the Aero Medical Laboratory at Wright Field, near Dayton (now Wright-Patterson Air Force Base).

However, the AAF psychologists were not alone :in the creation of the new discipline. Rather, they appear *to* have been part of a zeitgeist that led military psychologists *to* address issues regarding the design and operation of equipment. Essentially similar efforts had been taken from 1940 onward at the Applied Psychology Unit of Cambridge University :in the United Kingdom under the direction of Sir Frederic Bartlett. Like efforts took place :in Germany, too, but on a small scale (Fitts, 1946). For the United States, Kappauf stated matters quite clearly:

> When the Army and Navy recruited psychologists early in the war, assistance was sought primarily in the areas of selection and training of personnel.
>
> At the same time a few research programs sought the services of psychologists to insure the more satisfactory design of some items of military equipment, to insure design which would take account of particular psychological and physiological characteristics of human operators. Typical of this work was that which was initiated in the design of dark adaptation goggles, sun scanning devices, and communications equipment. As the war progressed this phase of research in applied psychology assumed greater and greater importance and involved more and more times of equipment. The field developed as much *through the initiative of individual psychologists* as it did through specific service requests. (1947, p. 83; emphasis added)

Most of those who were engaged :in military psychology during World War II left the Armed Services after the war, but not without having made their impact both on the conduct of the war and the future directions of psychology through their contributions to testing, selection, and classification; training and training devices; and the design and operation of equipment.

Postwar Engineering Psychology, 1946-1949

The growth of engineering psychology in the United States during the years immediately following World War II, from 1946 to 1949, was phenomenal, at least in comparison to its progress during the war. But there was reason for its slower growth during the war; as Grether observes," Although engineering psychology had its birth during World War II, the level of research effort in the United States was on a modest scale until after the end of hostilities in August 1945. This low level of effort was apparently deliberate, because it was recognized that only during a prolonged conflict could the benefits of such research be realized. Obviously, the time lag between initiation of engineering psychology research and the design, manufacture, and deployment of new or redesigned equipment is relatively long, often 5 years or more. Thus, during wartime it was more profitable for psychologists to concentrate on other types of research, such as selection and training, with faster payoff" (1968, p. 744).

After the war, when the Armed Services were demobilizing rapidly, in-house engineering psychology groups actually grew. It was late in August 1945 that Paul Fitts and a small group of psychologists were transferred to the AAF Aero Medical Laboratory. At about the same time, the Navy set up two engineering psychology units: one at the Naval Research Laboratory (Anacostia) under Franklin V. Taylor, and the second at the Navy Special Devices Center (Port Washington, New York) under Leonard C. Mead. The next year, the Navy established a third unit at the Navy Electronics Laboratory (San Diego) under Arnold M. Small. Both services also provided contract support for engineering psychology research at universities (e.g., the University of California at Berkeley, Harvard University, Johns Hopkins University, and the University of Maryland, among others), and at the Psychological Corporation, where Jack Dunlap had set up a Biomechanics Division for engineering psychology R&D. That division later became Dunlap and Associates.

Publications that were important stimuli to the growth of engineering psychology also appeared during this period. The publications were in journals; for example, Kappauf's paper was the first of three invited papers in the March 1947 issue of the *American Psychologist;* the other two were by Taylor and Fitts on psychology at the National Research Laboratory (NRL) and in the AAF, respectively. Books were also published-books that served both as texts for students in colleges and universities and as reference works for researchers in laboratories and R&D organizations. Among the more notable of these tests are:

- *Psychological Research on Equipment Design* edited by Fitts and appearing as Report Number 19 of the Army Air Forces Aviation Psy- chology Program, Research Reports (1947b);
- *Applied Experimental Psychology* by Chapanis, Gamer, and Morgan (1949);
- *A Survey Report on Human Factors in Undersea Warfare* by the Panel on Psychology and Physiology, Committee on Undersea Warfare, National Research Council (1949); and
- *Handbook of Human Engineering Data,* (the "Tufts Handbook") prepared under contract at Tufts College with support of the Naval Training Devices Center (1949).

It was also during this period that engineering psychology achieved recognition, not only in the academic community but also in the areas to which its findings were being applied. Successful applications were apparent in aircraft cockpits, combat information centers, fire-control systems, and sensor systems. Engineers in the airframe industry accepted, and often sought, the input of engineering psychologists for their designs.

There were still only a few engineering psychology laboratories in the Armed Services, but they were productive. The relatively small number of universities offering training and degrees in the field was growing (this is the period in which Paul Fitts joined the faculty of The Ohio State University). The success of Dunlap and Associates also portended growth in engineering psychology contractor firms. And thus, the decade ended.

The Early Growth of Engineering Psychology, 1950-1960

Grether (1968) characterizes the growth of engineering psychology during the decade from 1950 to 1960 as "explosive," and his characterization is accurate. Much of the growth took place within the existing engineering psychology units of the services, and to the existing units the Army now added its own organization in what later developed into the U. S. Army Human Engineering Laboratories at Aberdeen Proving Ground, Maryland.

The greatest increase was the establishment, within the defense industries, of human factors engineering groups, usually consisting of a majority or plurality of psychologists. Kraft (1961) reports that whereas there were only two industrial human factors activities in 1951, there 24 in 1956, and 157 in 1961.

Among the earliest of the independent contractors to seek and conduct human factors or engineering psychology R&D during the early

1950s, besides Dunlap and Associates, were Bob Sleight's Applied Psychology Corporation, Harry Older's Institute of Human Relations, and John Flanagan's American Institutes for Research.

Not surprisingly, toward the end of the decade, the growth pattern increased exponentially. The airframe and aerospace industries entered the picture by rapidly expanding their human factors activities. The reason for this is that the U.S. Air Force promulgated the personnel-subsystem concept that required early attention to the manpower, personnel, training, and human factors domains-the personnel-subsystem aspects of the system being designed and developed. The Air Force contracts of the day contained formal requirements for reports on qualitative and quantitative personnel requirements information (QQPRl), the types of training and simulators or training equipment that would be needed, and the human factors engineering and tests that were planned. Thus, the Air Force began requiring contractors to prepare data and analyses based on system concepts and designs that would help increase the efficiency and effectiveness of the personnel subsystem-the manning and training of the personnel who would be called upon to operate and maintain the system.

Important, too, were the new books that reached the market and the chapters that appeared during the 1950s. Among the most influential in terms of its impact on both the nature and the growth of the discipline was Paul Fitts's chapter "Engineering Psychology and Equipment Design" in Stevens's *Handbook of Experimental Psychology* (1951). Several generations of engineering psychology graduate students and fledgling professionals studied that chapter, nearly to the point of rote memory-which is to say, to a point just a little more intense than they studied all the other chapters of that monumental text!

The first edition of Ross McFarland's *Human Factors in Air Transportation* appeared in 1953, and during the next year, 1954, Wesley Woodson's *Human Engineering Guide for Equipment Designers* was published-the first of the several well-designed and readable guides or handbooks for human factors engineering practitioners that have appeared since then. Ernest McCormick's *Human Engineering* was published in 1957 and was the first textbook on the topic since Chapanis, Gamer, and Morgan's *Applied Experimental Psychology* in 1949.

The decade saw the publication of many chapters and reports on the topic of, or topics in, "engineering psychology"- for example, see the papers included in Wally Sinaiko's *Selected Papers on Human Factors in the Design and Use of Control Systems,* which appeared in 1961 and was widely used as an adjunct to the primary texts of courses in engineering psychology. The decade also saw the beginnings of growth in the publication of specialized texts and reports, such as Floyd and Welford's *Symposium on Fatigue* (1953); Finch and Cameron's *Air Force Human Engineering, Personnel, and Training Research* (1958); and Ray, Martin, and Alluisi's *Human Performance as a Function of the Work-Rest Cycle* (1961).

The third indication of growth during the 1950s was the formation of two societies to represent the profession and science of human factors engineering and engineering psychology. In the Far West, especially in Southern California in the area from Los Angeles south to San Diego-the area in which many of the airframe and aerospace industries were located-persons interested in the new emphasis on "human factors" began meeting together for technical discussions. These meetings led to the formation of the Human Factors Society (HFS) in 1957, which, in tum, produced the journal *Human Factors,* intended as an archival journal for the publication of research findings, and the *HFS Bulletin,* a newsletter that also carries papers of a substantive nature pertaining principally to professional affairs.

The Human Factors Society was from the very beginning a multidisciplinary organization that accepted as members anyone who worked or even expressed interest in any of the multiple areas of human factors-areas dealing with considerations of human factors as they influence or ought to influence the design and operation of systems, including aspects such as human-machine interfaces, product and workplace designs, and safety. Although at its beginning between a third and a half of its members were psychologists, the Human Factors Society has never been viewed as a "psychological society," nor has it indicated any desire to be so perceived. However, the situation was different on the East Coast. There, Franklin Taylor, Karl Kryter, and Harry Older organized Division 21, the Society of Engineering Psychologists-A Division of the American Psychological Association.

The Founding and Early History of Division 21

Franklin V. Taylor was the principal founder of Division 21, in the sense that he provided much (if not most) of the initiative and drive. At the time, he headed the Psychology Branch at the Naval Research Laboratory, and he solicited the cooperation of Karl Kryter, who was chief of the Human Factors Research Laboratory at Bolling Air Force Base, located not far from NRL. He also sought and obtained the interest, cooperation, and help of Harry J. Older, the president of the Institute of Human Relations, a contracting organization that did work in engineering psychology.

In January 1954, Kryter, Older, and Taylor sent a letter to the heads of all the engineering psychology groups in the United States. The letter listed the APA requirements to be met and procedures *to* be followed and invited interested parties to join in signing a draft petition to establish a new division "to represent the interests of members of the APA in the field of Engineering Psychology." Crawford reports that "association bylaw statements about divisions did not change much from 1946 to 1970. The minimum number required to petition for recognition of a new division was changed from the fixed number or 50 to 1% of the APA membership" (1992, pp. 187-188).

As I recall it, the changes took place in steps, and an even 100 signatures were required at the time of the engineering psychology petition. Responses and signatures were received, but so were some objections and negative reaction. The questions and objections raised were typical of the times in expressing concerns about the proliferations of divisions and fears of further splintering the APA. As Crawford documents the two sides of the issue, "During the late 1950s, the Council of Representatives debated vigorously each petition to form a new division. Some members of the Council resisted on grounds of fragmentation and increasing complexity of the APA. Others felt that the health of psychology would be enhanced by letting divisions proliferate, so long as they met the criteria stated in the Bylaws. Thus, between 1945 and 1970, 12 new (divisions] were recognized" (1992, p. 188).

In any event the required number of signatures was obtained or exceeded, and in March 1954, Kryter, Older, and Taylor sent a letter presenting the petition, the signatures, and some arguments for its approval to the well-liked APA executive secretary Fillmore H. Sanford, whose physical height and size were so great that he was frequently introduced as "one of the biggest men in psychology."
Ostensibly after considerable debate, the APA's Policy and Planning Board and the Board of Directors approved the new division contingent on no objections from the existing divisions. There were none, apparently, and the Society of Engineering Psychologists-A Division of the American Psychological Association was recognized as APA Division 21 in 1956.

I recall being in Paul Fitts's office and overhearing his side of a telephone conversation with Frank Taylor regarding the name to enter on the petition for the new APA division. Some supporters favored "human engineering/' "human factors engineering/' "human factors/' "human factors psychology/' or "applied experimental psychology." Fitts, as always, was courteous, but he was also steadfast in expressing his preference for "engineering psychology." He observed that the use

of "human factors" was preempted by the formation of the society bearing that name, and he felt that some persons thought "human engineering" too imprecise, not correctly descriptive, and inadequate in failing to indicate that the division was one of psychologists dealing with a legitimate (albeit a new) area of psychology. "Applied experimental psychology" seemed somewhat broad and appeared to some to be too awkward or pretentious a name for the discipline. Although I did not hear the other end of the conversation, I did hear Fitts agree that the name "Society of Engineering Psychologists" was both properly descriptive and an acceptable compromise to satisfy those who did not want to say that there was a substantive "engineering" sub-area of psychology-the "science of behavior."

Although recognized as APA Division 21 in 1956 (Crawford, 1992, pp. 187-189), the society lacked the necessary infrastructure and institutional history to operate its own, so Kryter, Older, and Taylor continued to handle the division's affairs. For example, they solicited the members for nominations and arranged for the election of officers and the scheduling of the first divisional meeting.

Grether (1968) indicates that the division began to operate in 1957, and that appears to be accurate because the first business meeting was held then in New York City in conjunction with the annual meeting of the APA. At that business meeting, the first officers were installed: President, Paul M. Fitts; president-elect, Franklin V. Taylor; secretary, Harry J. Older; and representatives to the APA Council, Alphonse Chapanis and Harry J. Older. Among the other actions taken at the first meeting were motions passed to study affiliations with other societies, the training of engineering psychologists, and the possibility of publishing a journal of engineering psychology.

The first postwar convention not held on a college campus was the APA's 59th annual meeting in 1951 in Chicago. The headquarters hotel room rates ranged from $5 to $10 for a single, and from $7.50 to $14 for a double *(American Psychologist* [195n 3, 83). Even 16 years later, in 1967, 10 years after Division 21's first meeting, when the APA's convention was held in Washington, the room rates at the convention headquarters hotels (the Shoreham, Sheraton Park, and Washington Hilton) ranged from $12 to $16 for a single, and from $16 to $20 for a double or twin *(American Psychologist* [19671t *19,* 267).

But something even more momentous than the first meeting of the Society of Engineering Psychologists occurred in 1957-the USSR launched the first Sputnik. The news of that event so surprised and shocked the American public that it fostered a spectacular growth in federal support for science and technology, especially in the aerospace arenas, including those segments of engmeering psychology R&D and human factors engineering that were perceived to have relevant contributions to make.

Sputnik also provided the stimulus for the creation of the National Aeronautical and Space Administration (NASA) and the Advanced Research Projects Agency (ARPA, which has become DARPA since the addition of the prefix *Defense),* and for substantial increases in financial support for the in-house Armed Service laboratories, as well as the aerospace industries that employed engineering psychologists. The division prospered, and the discipline seemed destined for inevitable success were it only to stay the course of addressing issues of importance to the customer.

When the customer is one of the Armed Services and the product is a weapon system, the important issue is to develop a system that will reach its full engmeering (bench-level) capability efficiently and effectively when operated and maintained by personnel in the field. The human factors input for the design and development of such successful systems is prominently based on the knowledge and technology discovered or created by engineering psychologists via applications of scientific methods to practical problems.

Just after the end of World War I, Edward L. Thorndike said some things that are as applicable today to APA Division 21, the Division of Applied Experimental and Engineering Psychologists, as they were in December 1918 when he gave his vice-presidential address before Section H, Anthropology and Psychology, at the annual meeting of the AAAS in Baltimore:

> The applied psychology or human engineering which has been developing so rapidly in the last decade has learned, in the war, if not before, that nothing short of the best in either ideas or men can do its work Applied psychology is much more than cleverness and common sense using the facts and principles found in the standard texts. It is scientific work, research on problems of human nature complicated by conditions of the shop or school or army, restricted by time and labor cost, and directed by imperative needs.
>
> The secret of success in applied psychology or human engineering is to be rigorously scientific. Making psychology for business or industry or the army is harder than making psychology for other psychologists, and intrinsically requires higher talents. Psychology applied to the complicated problems of personnel work represents scientific research of the most subtle, involved, and laborious type. (1919, p. 60)

And so it is, even to today! *Stay the* course-scientific methods, timely responses, issues important to the customers-and both the organization and the discipline, APA Division 21 and engmeering psychology, will be destined to succeed.

References

Anon. (1919). The measurement and utilization of brain power in the army. *Science*, 49, n.s., 221-226

Chapanis, A., Garner, W. R., & Morgan, C. T. (1949). *Applied experimental psychology.* New York: Wiley.

Crawford, M.P. (1992). Rapid growth and change at the American Psychological Association: 1945 to 1970. In R. B. Evans, V. S. Sexton, & T. C. Cadwallader (Eds.), *The American Psychological Association: A historical perspective* (pp. 177-232). Washington, D.C.: APA.

Dunlap, K. (1918). Psychological observations and methods. In Y Henderson (Ed.), Medical studies in aviation. *Journal of the American Medical Association,* 71, 1382-1400.

Finch, G., & Cameron, F. (Eds.). (1958). *Air Force human engineering, personnel, and training research* (Publ. No. 516). Washington, D.C.: NAS-NRC.

Fitts, P. M. (1946). German applied psychology during World War IT. *American Psychologist,* 1, 151-161.

Fitts, P. M. (1947a). Psychological research on equipment design in the AAF. *American Psychologist,* 2, 93-98.

Fitts, P.M. (Ed.). (1947b). *Psychological research on equipment design* (Report No. 19 in Army Air Forces, Aviation Psychology Program, Research Reports). Washington, D.C.: U.S. Government Printing Office.

Fitts, P. M. (1951). Engineering psychology and equipment design. In S. S. Stevens (Ed.), *Handbook of experimental psychology* (pp. 1287-1340). New York: Wiley.

Flanagan, J.C. (Ed.). (1948). The Aviation Psychology Program in the Army Air Forces (Report No. 1 in *Army Air Forces, Aviation Psychology Program, Research Reports).* Washington, D.C.: U.S. Government Printing Office.

Floyd, W. F., & Welford, A. T. (Eds.). (1953). *Symposium on fatigue.* London: H. K. Lewis.

Grether, W. F. (1968). Engineering psychology in the United States. *American Psychologist*, 23, 743-751

Henderson, Y (Ed.). (1918). Medical studies in aviation. *Journal of the American Medical Association,* 71, 1382-1400

Kappauf, W. E. (1947). History of psychological studies of the design and operation of equipment. *American Psychologist,* 2, 83-86.

Kraft, J.A. (1961). A 1961 compilation and brief history of human factors research in business and industry. *Human Factors, 4,* 253-283.

McCormick, E. (1957). *Human engineering.* New York: McGraw-Hill.

McFarland, R. (1953). *Human factors* in *air transportation.* New York: McGraw-Hill.

Melton, A.W. (1957). Military psychology in the United States of America. *American Psychologist,* 12, 740-746.

Panel on Psychology and Physiology, Committee on Undersea Warfare. (1949). *A survey report on human factors in undersea warfare.* Washington, D.C.: National Research Council.

Ray, J. T., Martin, O. E., Jr., & Alluisi, E. A (1961). *Human performance as a function of the work-rest cycle* (Publ. No. 882). Washington, D.C.: NAS-NRC.

Sinaiko, H. W. (1961). *Selected papers on human factors in the design and use of control systems.* New York: Dover.

Taylor, F. V (1947). Psychology at the Naval Research Laboratory. *American Psychologist,* 2, 87-92.

Thorndike, E. L. (1919). Scientific personnel work in the Army. *Science, 49, n.s.,* 53-61.

Tufts College & U.S. Naval Training Devices Center. (1949). *Handbook of human engineering data.* Medford: Author.

Uhlaner, J. E. (1968). *The research psychologist in the army-1917 to 1967* (Tech. Res. Rep. 1155). Arlington: U.S. Army Behavioral Science Research Laboratory.

Woodson, W. (1954). *Human engineering guide for equipment designers.* Berkeley: University of California Press.

Yerkes, R M. (1919). Report of the psychology committee of the National Research Council. *Psychological Review, 26,* 83-149.

Yerkes, R M. (Ed.). (1921). *Psychological examining in the United States Army* (VoL 15, *Memoirs of the National Academy of Sciences).* Washington, D.C.: U.S. Government Printing Office.

Paul Morris Fitts, 1912-1965

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Professor Fitts was at once my teacher, advisor, professional colleague and friend and neither of us made much of a distinction among these roles. [1]

In May 1965, just three days short of his fifty-third birthday, Paul M. Fitts went up to his bedroom in Ann Arbor, Michigan, for a rest before receiving faculty and students planning to attend a party at his home. He never woke up. A massive heart attack took a life in its prime. He had just begun to advance a theory of human performance-human performance as opposed to human perception or information processing-because he was interested in a theory of psychology that could be interpreted in terms of applications rather than one that simply provided grist for the academic milL Although his perspectives predated those of Neisser, he would have subscribed to Neisser's view that "psychology is not just something to do until the biochemist comes" (Neisser, 1967). Paul's significance to the field lies in the fact that he refused to constrain himself to be either an experimental psychologist or an engineering psychologist. He saw both roles as one. He not only believed, but also repeatedly acted on the belief, that the work of the experimental psychologist and that of the engineering psychologist are both parts of an integrated view of behavior and of the research needed to understand it.

Personal History

Before discussing his significant research contributions I will present a little history to set the stage: Paul Morris Fitts was born in 1912 in Martin, Tennessee. He received his bachelor of science in psychology at the University of Tennessee in 1934, his master of arts at Brown University in 1936, and his Ph.D. in psychology at the University of Rochester

1. Quoted from the acknowledgment to my dissertation at the University of Michigan (Pew, 1963).

in 1938, under Leonard Carmichael. He immediately returned to the University of Tennessee as an assistant professor. Up to that point in his career he was, for all intents and purposes, a *urat* psychologist/' seek- ing to advance the understanding of animal motivation (Fitts, 1940).

That all changed in April 1941, when he was enticed to move to Washington, D.C., to join a collection of psychologists committed to the war effort. They were working with the U.S. Army Air Forces in the Office of the Air Surgeon on the problems of selecting and training future Air Corps pilots. Fitts was to serve the Air Forces for more than eight years, first as a civilian and then for four and a half years as an Air Force officer, rising from first lieutenant to lieutenant colonel by the time of his discharge in October of 1946, and then for another three years as a civil servant. There is no documentation to explain his metamorphosis from animal psychologist to applied experimental psy- chologist, but one supposes that it was easy to get caught up in the war effort and from that point he never looked back.

During this period the military began to see that there were a number of roles for psychologists in the Armed Services. Issues of selection and training were self-evident from the beginning. However, during the course of the war a new and unexpected role emerged-the role of determining how to design equipment to adapt it to human require- ments.

> Interest in psychological problems of equipment design developed rapidly during the recent war. The intense effort to produce new weap- ons, the race against time in industrial production, and the magnitude of the program required to train men to operate these new machines re- sulted inevitably in many instances in which the final man-machine combination failed to function effectively. . . .
>
> The principal difference between engineering psychology and the other special fields of psychology is in point of view and final objectives. In most fields of applied psychology, and clinical psychology in particular, the interest is in changing the individual or in placing the individual in an environment or in a work situation where he can adapt successfully. Engineering psychology is concerned with adapting one important aspect of the environment, the machines of a technological society, to man's own requirements. Broadly conceived, the techniques of engineering psychology can be applied *to* many aspects of our present-day industrial civilization for the purpose of improving them in terms of human requirements. (Fitts, 1947, pp. 2-3)

The first equipment-design research in the Air Forces was carried out in approximately 1943 by the Department of Psychology of the AAF

School of Aviation Medicine, of which Arthur W. Melton was the director.

On July 1, 1945, the Psychology Branch of the Aero Medical Labora- tory was established at Wright Field in Dayton, Ohio. Paul Fitts, at the age of 33, was appointed its first director, and it soon became the unit responsible for all aspects of engineering psychology for the Army Air Forces. In preparation for this assignment Paul was sent for three months of temporary duty to tour the major German universities and research centers and study the techniques and procedures that German psychologists used in support of the war effort (Fitts, 1946). He found extensive work related to selection, testing, and training that paralleled U.S. efforts and a limited amount of equipment research that focused on the design of gun sights and control devices. Extensive use was made of psychological testing, but, rather than rely on the test scores, the administrators used the tests as a means for eliciting behavior to which they could apply clinical judgment. There were no attempts *to* assess the predictive validity of the tests or procedures and, in fact, very little use was made of statistics (Fitts, 1946).

At the Psychology Branch, Paul interpreted his administrative duties to include setting the research agenda for the branch, and he found it impossible not be become involved in several studies. From this period he is probably best known for the pioneering analysis of pilot error experiences in reading and interpreting aircraft instruments and in operating aircraft controls (Fitts & Jones, 1947a, 1947b). These studies drew on the critical incident methodology introduced by Flanagan (1954) in which open-ended interviews were conducted *to* elicit reports of accidents or near accidents. Fitts and Jones then cataloged those incidents on the basis of the design features *to* which they could be attributed. In addition *to* several design impacts that could be ad- dressed directly, the studies stimulated research in the Air Force for many years to come. The instrument reading study was the first *to* document problems with reading the three-pointer altimeter. The Avia- tion Safety Reporting System (ASRS), an extensive NASA database of commercial aircraft incidents anonymously reported and used widely for research, may be regarded as a contemporary manifestation of this early work. Today, Building 248, which houses much of the Human Engineering Division of the Armstrong Laboratory, the successor to the Psychology Branch, is dedicated *to* Paul Fitts's memory.

In 1949 Paul returned to the academic environment at Ohio State University and reactivated the Laboratory of Aviation Psychology, which had been inactive since the January 1949 death of its founder, Floyd D. Dockeray, a professor of psychology at the university since 1929 and an aviator during World War I. Paul's laboratory was later renamed the Systems Research Laboratory when it ceased to be dominated by aviation research. He remained at Ohio State, active in research, teaching, and administration, and on the national scene until 1958, when he was lured by his old friend and colleague Arthur W. Melton to move to the University of Michigan, where he remained until his untimely death.

At Michigan, he was active in a variety of interdisciplinary programs, including the Communication Sciences Program, initially a speech-science program instituted by Gordon Peterson that later became the incubator for the burgeoning field of computer sciences at Michigan, and at the Mental Health Research Institute, where James Grier Miller was promoting broadly based behavioral sciences research from the perspective of general systems theory. In 1963, Paul joined with three other Michigan psychology department faculty members-Arthur W. Melton, Ward Edwards, and William L. Hays-to form the Human Performance Center. The HPC was a research unit of the department that was initially funded by the Advanced Research Projects Agency of the Department of Defense and brought together a critical mass of students and faculty. Within a little more than a year it consisted of nine faculty- and scientist-level appointments-Pitts, Melton, Edwards, Hays, Edwin Martin, Judith Goggin, Richard Pew, Cameron Peterson, and F. Lee Beach-and by the time of his death two years later it was supporting more than 15 graduate students.

Intellectual History

It seems likely that Paul introduced the term *engineering psychology.* If he did not actually introduce it, surely he was the first to popularize it and influence its adoption to represent psychology's interests in the human's role in system design and development. He used it in his introduction to a series of Psychology Branch research papers in 1947 to refer to the emerging area of psychological research on equipment design (Fitts, 1947). In 1951 the term became the centerpiece of the title of a chapter in Stevens's *Handbook of Experimental Psychology* (Fitts, 1951). This chapter was especially significant because it was in the most widely assigned sourcebook for experimental psychology graduate students for more than ten years and thereby brought engineering psychology to the attention of mainstream psychological researchers.

Throughout his career, Paul Fitts championed the application of psychological research to equipment or systems design. He accomplished this initially through his own research, but after he left the Air Force his work took a more academic turn, emphasizing research questions that had a payoff in applied work. His direct impact on engineering design continued to be felt through his consulting and in his participation in significant engineering psychology developments nationally. He was instrumental in helping to organize Division 21 of the APA, the division concerned with applied experimental and engineering psychology. He was a founding member and later president of the Human Factors Society. He was chair of several psychology and social science panels, boards, and committees sponsored by the Air Force, the Department of Defense, and the National Research Council that were influential in establishing a role for engineering psychology.

Although the scope of Paul's theoretical and applied interests were very broad, his research had a thread of continuity and specificity that gave it focus. His original interests were stimulated by his introduction to issues from the applied perspective at the Psychology Branch of the Aero Medical Laboratory, and he sustained work on them virtually throughout his career, generalizing and broadening their importance and impact at each new opportunity. All these topics fell under the general rubric that he would come to call "human skilled performance." His interest in human skilled performance continued unabated until 1965. In this domain there were three main thrusts to his own research: (1) Inferring the characteristics of human information processing from objective measurement, particularly reaction time; (2) stimulus-response (S-R) compatibility; and (3) visual-motor tracking, movement control, and the prediction of movement time from accuracy and distance requirements.

Human Information Processing

Initially, the work of the Psychology Branch was focused on the design of cockpit controls and displays. On the display side, the issue was design to promote efficiency of interpretation. This presented Paul's first opportunity to think about the design issues associated with the speed and accuracy of mental interpretation. As early as 1946, he proposed that displays should be designed for (1) quick perception; (2) immediately apparent meaning; (3) distinguishable displays; and (4) the grouping of displays presenting related information (Fitts, 1946). With respect to display location, he said, "It has been proposed, for example, to throw the image of certain instruments onto the wind screen so that they can be viewed while looking out of the plane" (Fitts, 1946, p. 272). This must be one of the earliest references to the concept of the head-up display. An Air Force study in 1947 specifically addressed pilot reaction time to comprehend and react to contact flight[2] and instrument recovery from disorientation (Fitts, Jones, Milton, & Norris, 1947).

Paul's interest in information processing began because he was interested in using reaction time and related measures to infer the efficiency of performance in practical settings. However, at Ohio State this work began to take on a more analytic flavor. He participated with his colleagues on studies of incentives on reaction time (Bahrick, Fitts, & Rankin, 1952); the learning of sequential dependencies (Bennett, Fitts, & Noble, 1954); and used secondary task performance as a measure of the degree of learning of a primary task (Bahrick, Noble, & Fitts, 1954), an early undertaking in the spirit of contemporary studies of workload using secondary tasks.

During the 1950s Claude Shannon introduced his seminal work on information theory and the idea that information could be treated as a commodity that could be manipulated and measured quantitatively as a distribution on a probability space (Shannon & Weaver, 1949). 1bis work had a profound impact on psychology especially on the applied aspects of information processing, because it held out the promise that practical information processing tasks could be quantified and evaluated in relation to human capacities. As did many others, Paul became interested in these methods. He pursued them in three areas: (1) pattern recognition; (2) reaction time; and (3) motor performance.

Pattern Recognition

In the sphere of pattern recognition, following Attneave (1959), Paul generated "metric patterns" as stimuli for which the stimulus variability was defined statistically, incorporating stimulus redundancy reflecting two different kinds of constraints (Adams, Fitts, Rappaport, & Weinstein, 1954; Fitts, Weinstein, Rappaport, Anderson, & Leonard, 1956). He found that the speed of pattern recognition could be either slowed down or speeded up, depending on how the redundancy was generated. Pickett (1964) used a variant of the generating process for these figures to study the perception of stimulus regularity, and Posner (1962) built on these studies in his award-winning thesis that attempted to broaden the quantitative analysis of information handling to include

2. The term used to refer to flight on the basis of visual reference through the windscreen.

information reduction and, in his later studies, introduced the idea of pattern recognition schema (Posner & Keele, 1968).

Reaction Time

Research exploring the variables affecting human reaction time continued to challenge Paul throughout his career. His early efforts were directly in the spirit of extending the work of Hick (1952) and Hyman (1953) to consider serial reaction time and whether the rate of gain of information, as expressed in terms of information-theoretic variables, would trade off with changes in the rate of stimulus presentation or with sequentially defined redundancy. He found that increasing the rate of presentation produced continued gains in information transmit- ted in the case of verbal responses, but not in the case of motor responses involving the use of the fingers (Alluisi, Muller, & Fitts, 1957). In a further experiment extending this result, Anderson and Fitts (1958) found, using tachistoscopic presentation, that the amount of information gained could be increased only up to a point by increasing the information content of the stimuli, but that the limit was increased systematically by increasing the dimensionality of the stimuli. The information transmitted using colors or numbers presented alone peaked out as the amount of information per stimulus was increased, but did not when using stimuli consisting of the combination of colors and numbers. In the last two experiments in this series it was found that discrete versus serial presentation did not have an important impact on the reaction time to stimuli of varying information content, but the nature and familiarity of the stimulus-response (S-R) codes and their interrelation had a profound effect. Vocal responses to numbers produced reaction times that were virtually insensitive to information content, whereas vocal responses to stimulus lights and finger responses to both numbers and lights were affected by information content, as was expected (Brainard, Irby, Fitts, & Alluisi, 1962). Similarly, assigning highly associated letter responses to line-drawing picture stimuli produced faster responses than unassociated letters, but both sets showed that reaction time continued to improve over five sessions of practice (Fitts & Switzer, 1962). These results were interpreted in the context of Paul's previous work on S-R compatibility.

About this time, investigators (Mowbray & Rhodes, 1959; Leonard, 1959; Kornblum, 1969) began to question the ability of the information-theoretic view to predict limiting cases or the fine structure of reaction time as a function of stimulus variables, especially redundancy, although it continued to be a useful measure to apply in practical settings.

Paul's first reaction time research to depart from the analysis of information processing in terms of information-theoretic notions was published in 1963 (Fitts, Peterson, & Wolpe). It was also the first to place Paul in the mainstream of the new perspectives on modeling reaction time as a sequential decision process (Stone, 1960; Welford, 1960). It was the most comprehensive experiment on the effects of redundancy on response time to date, and he did not even analyze it in terms of information measures. It illustrated that both reaction time and the probability of error could be predicted qualitatively on the basis of the prior odds (expected relative frequency of each stimulus) and the subject's adaptation to behave consistently with those odds. The specificity of the model and the range of variables to which it could be applied were extended in a final experimental paper published shortly after he died (Fitts, 1966). It provided the most extensive data set showing the effect of specific manipulations of speed and accuracy of performance based on differential monetary payoffs and introduced a sequential-sampling Baysian statistical decision model as a comprehensive mechanism for explaining the effect of redundancy and set for speed versus accuracy. The theory also was consistent with the obtained distributions of response times for correct and error responses. This representation was further confirmed in subsequent work reported by Pachella and Pew (1968), Swensson and Edwards (1971), and Pew (1969).

Fitts's work on information processing had two important effects. First, by cataloging a wide range of variables and their interrelated effects on reaction time, he made a significant contribution to the effort to broaden the scope of (and legitimize the analysis of) human informa- tion processing that had been initiated by Broadbent (1958). Fitts thought of these projects as contributing to a theory of skilled or highly practiced performance (Fitts, 1964; Fitts & Posner, 1967). Second, he significantly impacted the methodology by which reaction time data were collected (Pachella, 1974). It became very important to control prior expectation about when and with what probability stimuli would occur. Instructions to respond as rapidly and accurately as possible were seen to introduce variability associated with each subject's inter- pretation of that instruction with respect to set for speed versus accu- racy. "Simple" reaction time came to be seen not to be so simple, but just a variant of choice RT in which one alternative was the non- occurrence of a stimulus. Finally, it became necessary to control for S-R compatibility of the stimulus and response sets.

Stimulus-Response Compatibility

The topic of stimulus-response compatibility provides a case study of how Paul took an observation of a practical problem and, through a coherent series of experimental studies, threaded it into the mainstream of psychological research. The starting point was undoubtedly his early critical incident studies of aircraft cockpit controls and displays (Fitts & Jones, 1947a, 1947b) One of the problems they found when examining incidents with aircraft instruments concerned the direction of motion of the artificial horizon.

This instrument is often referred to as the "attitude ball" because it shows a fixed aircraft symbol in front of a moving sphere that is stabilized to reflect the position of the real horizon with respect to the attitude of the aircraft itself. When the aircraft pitches up, the horizon line moves below the fixed aircraft symbol to reflect the fact that if the pilot looks out the windscreen, the horizon will appear below the nose of the aircraft. The problem is that if the pilot wishes to return to straight-and-level from a pitch-up position he or she must move the control stick forward. Experienced pilots do not have much difficulty with this, but novices, viewing the artificial horizon, expect that moving the stick forward will move the horizon bar further down, thus further exaggerating their pitch-up attitude. When outside visibility is restricted and pilots must rely on instruments, there is a tendency for novices to move the stick the wrong way to correct a pitch or roll deviation. There is an intrinsic incompatibility between the motion of the artificial horizon line and the movement of the control to correct it.

These problems of direction of motion relationships had been noted for some time. They occur in moving map navigational displays, in moving pointer and moving scale instruments. The idea that movement relationships should conform to "population stereotypes/' that is, to an individual's prior expectations, had already been articulated in unpublished work of Margaret Vince at the Applied Psychology Unit in Cambridge, England, and supported by work in Paul's laboratory by Melvin Warrick (1947). Paul and Mel had the insight to realize that it was not an issue of the stimulus itself or the response itself but the relationship between them, hence the term *control-display* or *stimulus-response* compatibility. He then formulated the Fitts and Seeger (1953) and the Fitts and Deininger (1954) studies to demonstrate that these results could be interpreted in terms of general principles. Fitts and Seeger (1953) showed that differing skilled performance could be related to the amount of recoding that was necessary to interpret spatially different response codes in terms of various stimulus codes.

Using all combinations of a matrix of three spatial stimulus arrangements and three response movement patterns, they showed that for each stimulus code there was a response code that produced the fastest response times and fewest errors, and that the best code was different for each of the three stimulus arrangements.

In Fitts and Deininger (1954) Paul generalized the definition of recoding to include symbolic as well as spatial codes, showing that translation of a numerical stimulus (clock code) into a response direction was more difficult and time-consuming than moving in the direction indicated by a spatially displayed arrow. Next J. R. Peterson (1965) attempted *to* quantify the effects of systematic geometric transformations and showed that the larger the stimulus set, the greater the decrements associated with the need to recode.

Paul's work on this subject culminated in an unpublished report generated while he was on leave at IBM during 1957 that sought *to* present S-R compatibility in terms of a propositional theory. He generated predictions of response time and errors based on independently measured values of associative strength reflected in the population stereotype. The theory applied *to* information transformation rules, the stability of the rules from trial block *to* trial block (as later developed in Schneider's work on automaticity, see Shiffrin & Schneider, 1977), and the partitioning of relevant from irrelevant information on the basis of easily distinguished concepts (related *to* Gamer's concept of integral and separable dimensions, see Gamer, 1962). With respect to spatial codes, S-R compatibility is relevant in figure-ground relations, command versus error information, the requirement for spatial transformations, the correspondence between the scales on which the stimuli and responses are judged, and when stimuli and responses are interpreted in different coordinate systems.

Clearly, a concept that began as a practical observation in a cockpit has, through systematic empirical demonstration, been brought into the mainstream of psychological thinking. See Proctor and Reeve (1990) for a contemporary view of thinking about S-R compatibility.

Movement Control

The final area to which Paul devoted significant research effort was the area of motor performance and movement controt again drawing ideas from applied settings and testing, shaping and broadening them until the psychological community was forced to deal with them. In the Air Force, movement research was stimulated by observations of control use and misuse and by the desire to understand human ability to

control the complex dynamical response associated with aircraft. This led, at Ohio State, *to* a series of studies of human tracking performance, sometimes referred *to* as "manual control." There is a large literature on the ability of a subject to follow a continuously moving target manually with a control stick A wide variety of variables must be considered, for example, the function driving the moving target the way the target is displayed, the nature of the control device and the dynamical relation between action of the stick, and the response of the target as presented on the display. Paul's contributions to this domain were systematic but not profound until, stimulated by his research and thinking about information theory and reaction time, he was led to seek a quantitative measure of information that could be related *to* movement performance.

In what is now perhaps his most famous paper (Fitts, 1954), he showed that an index of difficulty of a movement could be defined in information-theoretic terms that accurately predicted movement time as a function of the accuracy required of a movement and the distance moved. The greater the accuracy required, the slower the movement; the longer the distance moved, the slower the movement. In his original paper he calculated *IP,* the binary index of performance.

$$IP = -1/t[\log_2 W/2A]$$

Where *A* equals distance from the starting point *to* the center of the target, and *W* equals target width. The use of the log *to* the base 2 allows the term in brackets, the index of difficulty of the movement, to be expressed in bits, the information theoretic measure of uncertainty. In the original paper Paul evaluated the extent *to* which *IP,* measured in bits/sec., was constant across a range of movement amplitudes, target widths, and tasks, implying the constancy of the informational capacity of the movement system. He showed that it worked (1) for reciprocal tapping where the size and separation of the target plates was varied; (2) for disk transfer where the difference in the diameter of the disk hole and the peg onto which it was placed reflected the accuracy constraint; and (3) for a peg transfer task in which pegs were transferred *to* holes of different sizes. He even showed for each of these movement tasks that constancy was maintained when a weight was added to the subject's hand.

In later studies (Fitts & Peterson, 1964; Fitts & Radford, 1966) he worked directly with the linear movement time equation

$$MT = a + b\,[\log_2(2A/W)]$$

where *a* and *b* are constants that are estimated from the data. He showed that the linear prediction was robust for discrete or continuous movements and, under various instructions, rapid or accurate. Numerous investigators have examined the predictions in great detail, notably Welford (1968), and although marginal gains in predictive accuracy have been proposed by adjustments in the equation and it has been derived from many other perspectives (see Keele, 1968), the fundamental relationship and the robustness of the predictions have never been challenged. In subsequent work it has been shown to work for foot movements (Drury,1975), movements of the head (Soede, Stassen, van Lunteren, & Luitse, 1973), and even movements made with tweezers while looking through a binocular microscope (Langolf, Chaffin, & Foulke, 1976). Card, English, and Burr (1978) made it the centerpiece of their analysis of alternative computer input devices and showed that the mouse produced a movement-time function that was so close to that of an unencumbered hand movement as to deny the need to look further for more efficient devices. The equation has come to be called Fitts' Law because of its ubiquitously successful application.

Fitts's Views of Contemporary Research

It is speculative to forecast how Paul would have been involved today, or which contemporary result he would have influenced with his current research. After all, he would have been 82 in 1994. I suggest three areas he would find particularly attractive. First, I am sure he would be a player in the discussions of automaticity because that work, in a real sense, reflects a continuation of his interest in highly skilled performance and in the effects of practice on associative reaction time (Hasher & Zachs, 1979; Logan, 1988a, 1988b; Shiffrin & Schneider, 1977).

Second, although I think he would eschew artificial intelligence and neural net modeling because they are too far from the data of human performance, I believe Paul would appreciate the kind of sophisticated goal-based task analysis that has grown out of cognitive science and knowledge engineering approaches to task description. They empower a much broader interpretation of the scope of human performance that is accessible to study, and he was always seeking ways to bring the systematic methods of experimental psychology to bear on higher mental processes.

Finally, he would be deeply embroiled in the sophisticated discussions of movement control initiated by Schmidt, Zelaznik, Hawkins, Frank, and Quinn (1979) and Meyer, Smith, and Wright (1982). This is work that used Fitts' Law as its starting point, and Paul was never one

to shy away from a lively exchange of perspectives, especially when they were continually illuminated by new experiments and data.

In 1965 we lost a student of human skilled performance in his prime. Nevertheless, in his shortened life he had a greater impact on the science of psychology and the real world of application than most of us will experience reaching our full life expectancy.

References

Adams, O. S., Fitts, P. M., Rappaport, M., & Weinstein, M. (1954). Relations among some measures of pattern discriminability. *Journal of Experimental Psychology, 48,* 81-88.

Alluisi, E. A., Muller, P. F., Jr., & Fitts P. M. (1957). An information analysis of verbal and motor responses in a forced-paced serial task. *Journal of Experimental Psychology,* 53, 379-387.

Anderson, N. S., & Fitts, P.M. (1958). Amount of information gained during brief exposures of numerals and colors. *-Journal of Experimental Psychology, 56,* 263-269.

Attneave, F. (1959). *Applications of information theory to psychology.* New York: Holt.

Bahrick, H. P., Fitts, P. M., & Rankin, R. E. (1952). Effects of incentives upon reactions to peripheral stimuli. *Journal of Experimental Psychology,* 44, 400-406.

Bahrick, H .P., Noble, M., & Fitts, P. M. (1954). Extra-task performance as a measure of learning a primary task. *Journal of Experimental Psychology, 48,* 298-302.

Bennett, W. F., Fitts, P. M., & Noble, M. (1954). The learning of sequential dependencies. *Journal of Experimental Psychology, 48, 303-312.*

Brainard, R. W., Irby, T. S., Fitts, P. M., & Alluisi, E. A. (1962). Some variables influencing the rate of gain of information. *Journal of Experimental Psychology,* 63, 105-110.

Broadbent, D. E. (1958) *Perception and communication.* London: Pergamon Press.

Card, S. K., English, W. K., & Burr, B. J. (1978). Evaluation of mouse, rate-controlled joy stick, step keys and text keys for text selection on a CRT. *Ergonomics,* 21, 601-613.

Drury, C. G. (1975). Application of Fitts' Law to foot-pedal design. *Human Factors,* 17, 368-373.

Fitts, P.M. (1940). Preservation of non-rewarded behavior in relation to food deprivation and work requirement. *Journal of Genetic Psychology, 57,* 165-191.

Fitts, P. M. (1946). Psychological requirements in aviation equipment design. *Journal of Aviation Medicine,* 17, 270-275.

Fitts, P.M. (1947). Introduction to psychological research on equipment design. In P.M. Fitts (Ed.), *Psychological research on equipment design* (pp. 1-19). (Report No. 19 of the Army Air Forces Aviation Psychology Program Research Reports). Washington, D.C.: U.S. Government Printing Office.

Fitts, P. M. (1951). Engineering psychology and equipment design. In S. S. Stevens (Ed-t *Handbook of experimental psychology* (pp. 1287-1340). New York: J. Wiley and Sons.

Fitts, P. M. (1954). The information capacity of the human motor system in controlling the amplitude of movement. *Journal of Experimental Psychology,* 47(6), 381-391.

Fitts, P.M. (1964). Perceptual-motor skill learning. In A. W. Melton (Ed.) *Categories of human learning* (pp. 243-285). New York: Academic Press.

Fitts, P. M. (1966). Cognitive aspects of information processing ill. Set for speed versus accuracy. *Journal of Experimental Psychology,* 71(6), 849-857.

Fitts, P.M., & Deininger, R. L. (1954). S-R compatibility: Correspondence among paired elements within stimulus and response codes. *Journal of Experimental Psychology, 48,* 483-492.

Fitts, P. M., & Jones, R. E. (1947a). *Analysis of factors contributing to 460 "pilot-error" experiences in operating aircraft controls* (USAF Air Materiel Command Memorandum Report No. TSEAA-694-12).

Fitts, P. M., & Jones, R. E. (1947b). *Psychological aspects of instrument display. I. Analysis of 270 "pilot-error" experiences in reading and interpreting aircraft instruments* (USAF Air Materiel Command Memorandum Report No. TSEAA-694-12A).

Fitts, P. M., Jones, R. E., Milton, J. L., & Norris, J. B. (1947). *Pilot reaction time: A study of the time required by pilots to comprehend and react to contact and instrument recovery problems* (USAF Air Materiel Command Memorandum Report No. TSEAA-694-13A).

Fitts, P. M., & Peterson, J. R. (1964). Information capacity of discrete motor responses. *Journal of Experimental Psychology,* 67(2), 103-112.

Fitts, P.M., Peterson, J. R., & Wolpe, G. (1963). Cognitive aspects of information processing II. Adjustments to stimulus redundancy. *Journal of Experimental Psychology,* 65, 423-432.

Fitts, P.M., & Posner, M. I. (1967). *Human performance.* Belmont: Wadsworth Publishing, Brookes/Cole.

Fitts, P. M., & Radford, B. K. (1966). Information capacity of discrete motor responses under different cognitive sets. *Journal of Experimental Psychology,* 71, 475-482.

Fitts, P. M., & Seeger, C. M. (1953). S-R compatibility: Spatial characteristics of stimulus and response codes. *Journal of Experimental Psychology, 46,* 199-210.

Fitts, P.M., & Switzer, G. (1962). Cognitive aspects of information processing: I. The familiarity of S-R sets and subsets. *Journal of Experimental Psychology,* 63, 321-329.

Fitts, P.M., Weinstein, M., Rappaport, M., Anderson, N., & Leonard, J. A. (1956). Stimulus correlates of visual pattern recognition: A probability approach. *Journal of Experimental Psychology,* 51, 1-11.

Flanagan, J. C. (1954). The critical incident technique. *Psychological Bulletin,* 51(28), 28-35.

Garner, W R. (1962). *Information and structure as psychological concepts.* New York: J. Wiley & Sons.

Hasher, L., & Zachs, R. T. (1979). Automatic and effortful processes in memory. *Journal of Experimental Psychology: General, 108,* 356-388.

Hick, W. E. (1952). On the rate of gain of information. *Quarterly Journal of Psychology,* 4, 11-26.

Hyman, R. (1953). Stimulus information as a determinant of reaction time. *Journal of Experimental Psychology,* 45, 188-196.

Keele, S. W. (1968). Movement control in skilled motor performance. *Psychological Bulletin,* 70, 387-403.

Kornblum, S. (1969). Sequential determinants of information processing in serial and discrete choice reaction time. *Psychological Review,* 76(2), 113-131.

Langolf, G. D., Chaffin, D. B., & Foulke, J.A. (1976). An investigation of Fitts' Law using a wide range of movement amplitudes. *Journal of Motor Behavior, 8,* 113-128.

Leonard, J. A. (1959). Tactual choice reactions I. *Quarterly Journal of Experimental Psychology, 11,* 76-83.

Logan, G. D. (1988a). Toward an instance theory of automatization. *Psychological Review, 95,* 492-527.

Logan, G. D. (1988b). Automaticity, resources, and memory: Theoretical, controversies and practical implications. *Human Factors,* 30, 583-598.

Meyer, D. E., Smith, J. E. K., & Wright, C. E. (1982). Models for the speed and accuracy of aimed limb movements. *Psychological Review, 89,* 449-482.

Mowbray, G. H., & Rhodes, M. V. (1959). On the reduction of choice reaction times with practice. *Quarterly Journal of Experimental Psychology,* 11, 16-23.

Neisser, U. (1967). *Cognitive psychology.* New York: Appelton-Century-Crofts.

Pachella, R. G. (1974). The interpretation of reaction time in information-processing research. In B. H. Kantowitz (Ed.), *Human information processing: Tutorials in performance and cognition* (pp. 41-82). Hillsdale: Erlbaum.

Pachella R. G., & Pew R. W. (1968). Speed-accuracy tradeoff in reaction time: Effect of discrete criterion times. *Journal of Experimental Psychology,* 76, 19-24.

Peterson, J. R. (1965). *Effects of S-R coding on the rate of gain of information.* Ph.D. dissertation, The University of Michigan.

Pew, R. W (1963). *Temporal organization in skilled performance.* Ph.D. dissertation, The University of Michigan.

Pew, R. W. (1969). The speed-accuracy operating characteristic. Attention and Performance II. *Acta Psychologica,* 30, 16-26.

Pickett, R. M. (1964). The perception of visual texture. *Journal of Experimental Psychology,* 68, 13-20.

Posner, M. I. (1962). *An informational approach to thinking.* Ph.D. dissertation, The University of Michigan.

Posner, M. I., & Keele, S. W. (1968). On the genesis of abstract ideas. *Journal of Experimental Psychology,* 77, 353-363.

Proctor, R. W., & Reeve, T. G. (1990). *Stimulus-response compatibility: An integrative perspective.* New York: Elsevier.

Schmidt, R. A., Zelaznik, H., Hawkings, B., Franks, J. S., & Quinn, J. T., Jr. (1979). Motor-output variability: A theory for the accuracy of rapid motor acts. *Psychological Review,* 86, 415-451.

Shannon, C. E., & Weaver, W. (1949). *The mathematical theory of communication.* Urbana: University of Illinois Press.

Shiffrin, R. M., & Schneider, W. (1977). Controlled and automatic human information processing. II. Perceptual learning, automatic attending, and a general theory. *Psychological Review, 84,* 127-190.

Soede, M., Stassen, H. G., van Lunteren, A., & Luitse, W. J. (1973.) A light spot operated typewriter for physically handicapped patients. *Ergonomics, 16,* 829-844.

Stone, M. (1960). Models for choice-reaction time. *Psychometrika,* 25, 251-260.

Swensson R. G., & Edwards, W. (1971). Response strategies in a two-choice reaction task with continuous cost for time. *Journal of Experimental Psychology, 88, 67-81.*

Warrick, M. J. (1947). Direction of movement in the use of control knobs to position visual indicators. In P. M. Fitts (Ed.), *Psychological research on equipment design* (pp. 137-146). (Report No. 19 of the Army Air Forces Aviation Psychology Program Research Reports). Washington, D.C.: U.S. Government Printing Office.

Welford, A T. (1960). The measurement of sensory-motor performance: Survey and reappraisal of twelve year's progress. *Ergonomics,* 3, 189-230.

Welford, A T. (1968). *Fundamentals of skill.* London: G. B. Methuen.

Publications of Paul M. Fitts

Except where noted, Paul M. Fitts is the sole author of the publication listed.

1940

———. Preservation of non-rewarded behavior in relation to food-deprivation and work-requirement. *Journal of Genetic Psychology, 57,* 165-191.

1942

———. An analysis of the reasons stated in faculty board proceedings for eliminating cadets from pilot training. *Analysis of Duties of Aircrew Personnel, Bulletin Number 1,* 20 November, 1-8.

---. *The aviation cadet qualifying examination-a report of the purpose, development, and validation of test AC10A* (Special publication of the Air Surgeon, Headquarters AAF), October, 1-44.

———. The flexible gunner. *Analysis of the Duties of Aircrew Personnel, Bulletin Number* 10, 7 September, 1-11.

———. The glider pilot. *Analysis of the Duties of Aircrew Personnel, Bulletin Number 9,* 28 August, 1-12.

---. Interview with members of the 19th Bombardment Group. *Analysis of the Duties of Aircrew Personnel, Bulletin Number* 13, 22 December.

---. A study of one hundred reclassified pilots. *Analysis of the Duties of Aircrew Personnel, Bulletin Number* 14, 23 December, 1-12.

1943

—— *Psychological traits of successful pilots-research findings of 1942* (Special publication of the Air Surgeon, Headquarters AAF), February, 1-25.

1944

———. *A study of gunners returned from combat* (Special publication by the Air Surgeon, Headquarters AAF), December, 1-21.

Flanagan, J. C., & Fitts, P.M. Psychological testing program for the selection and classification of air crew officers. *Air Surgeon's Bulletin,* 1(6), 1-5.

1946

---. German applied psychology during World War II. *American Psychologist, 5,* 151-161.

———. Psychological requirements in aviation equipment design. *Journal of Aviation Medicine,* 17, 270-275.

1947

———. Psychological research on equipment design in the AAF. *American Psychologist,* 2, 93-98.

———, (Ed.). *Psychological research on equipment design.* Vol. 19. The Aviation Psychology Research Program of the Army Air Forces. Washington: Government Printing Office.

Fitts, P. M., & Jones, R. E. *Analysis of factors contributing to 460 "pilot-error" experiences in operating aircraft controls* (USAF Air Materiel Command Memorandum Report No. TSEAA-694-12), 1 July.

Fitts, P.M., & Jones, R. E. *Psychological aspects of instrument display.* I. *Analysis of 270 "pilot-error" experiences in reading and interpreting aircraft instruments* (USAF Air Materiel Command Memorandum Report No. TSEAA-694-12A), 1 October.

Fitts, P.M., Jones, R. E., Milton, J. L., & Norris, J. B. *Pilot reaction time: A study of the time required by pilots to comprehend and react to contact and instrument recovery problems* (USAF Air Materiel Command Memorandum Report No. TSEAA-694-13A), 24 May.

Fitts, P. M., Milton, J. L., & Jones, R. E. *Investigation of errors made by pilots in judging the attitude of an aircraft without the aid of vision* (USAF Air Materiel Command Memorandum Report No. TSEAA-694-13), 2 May.

1950

Hartman, B. O., & Fitts, P. M. *The development of techniques and procedures for the study of alertness in aviation personnel* (Committee on Aviation Psychology), National Research Council, November.

1951

--. Engineering psychology and equipment design. In S. S. Stevens (Ed.), *Handbook of experimental psychology* (pp. 1287-1340). New York: Wiley.

———, (Ed.). *Human engineering for an effective air-navigation and traffic-control system.* Washington, D.C.: National Research Council.

1952

Bahrick, H. P., Fitts, P.M., & Rankin, R. E. Effects of incentives upon reactions to peripheral stimuli. *Journal of Experimental Psychology, 44,* 400-406.

———. Men and machines: The design of equipment for efficient human use. *Engineering Experiment Station News, 24,* 6--10.

Fitts, P. M., & Simon, C. W. Some relations between stimulus patterns and performance in a continuous dual-pursuit task. *Journal of Experimental Psychology,* 43,428-436.

Warren, C. E., Fitts, P.M., & Clark, J. R. An electronic apparatus for the study of the human operator in a one-dimensional closed-loop continuous pursuit task. *AIEE Transactions,* 71, sec. T2-8.

1953

———. The design of equipment and tasks for efficient use of human visual capacity. *Engineering Experiment Station News,* 25,9-13.

Fitts, P.M., Marlowe, E., & Noble, M. E. The interrelations of task variables in continuous pursuit tasks: I. Visual-display scale, arm-control scale, and target frequency in pursuit tracking. *Human Resources Research Center, Research Bulletin,* September, 53--54.

Fitts, P.M., & Seeger, C. M. S-R compatibility: Spatial characteristics of stimulus and response codes. *Journal of Experimental Psychology, 46,* 199-210.

Meyer, D. R., Bahrick, H.P., & Fitts, P.M. Incentive, anxiety, and the human blink rate. *Journal of Experimental Psychology, 45,* 183-187.

Noble, M. E., Fitts, P.M., & Marlowe, E. The interrelations of task variables in continuous pursuit tasks: II. Visual-display scale, arm-control scale, and target frequency in compensatory tracking. *Human Resources Research Center, Research Bulletin,* December, 53-55.

1954

Adams, O. S., Fitts, P.M., Rappaport, M., & Weinstein, M. Relations among some :rp.easures of pattern discriminability. *Journal of Experimental Psychology, 48,* 81-88.

Allen, M. J., Fitts, P. M., & Slivinske, A J. *A moving target optical projector for use in air traffic control research* (Wright Air Development Center, Tech. Rep. 53-417), Wright-Patterson Air Force Base, January.

Bahrick, H. P., Noble, M. E., & Fitts, P. M. Extra-task performance as a measure of learning a primary task. *Journal of Experimental Psychology, 48,* 298-302.

Bennett, W. F., Fitts, P.M., & Noble, M. The learning of sequential dependencies. *Journal of Experimental Psychology,* 48,303-312.

———. The influence of response coding on performance in motor tasks. In MacMillan et al. (Eds.), *Current trends in information theory* (chap. 3). Pittsburgh: University of Pittsburgh Press.

———. The information capacity of the human motor system in controlling the amplitude of movement. *Journal of Experimental Psychology,* 47, 81-88.

---. Research in some areas of overlap between psychology and engineering. *Engineering Experiment Station News, 26,* 64--69.

Fitts, P.M., & Deininger, R. L. S-R compatibility: Correspondence among paired elements within stimulus and response codes. *Journal of Experimental Psychology,* 48,483-492.

Kraft, C. L., & Fitts, P.M. *A broad band blue lighting system for radar air traffic control centers* (Wright Air Development Center, Tech. Rep. 53--416), Wright-Patterson Air Force Base, January.

1955

Alluisi, E. A., Muller, P. F. Jr., & Fitts, P.M. *Rate of handling of information and the rate of information presentation* (Wright Air Development Center, Tech. Note 55-745), Wright-Patterson Air Force Base, 1-13.

Bahrick, H. P., Bennett, W. F., & Fitts, P. M. Accuracy of positioning responses as a function of spring loading in a control. *Journal of Experimental Psychology, 49,* 437-444.

Bahrick, H.P., Fitts, P.M., & Schneider, R. Reproduction of simple movements as a function of factors influencing proprioceptive feedback. *Journal of Experimental Psychology,* 49,445-454.·

Deininger, R. L., & Fitts, P. M. Stimulus-response compatibility, information theory and perceptual-motor performance. In H. Quastler (Ed.), *Information theory in psychology: Problems and methods* (pp. 316--341). Glencoe: Free Press.

---. *Stimulus determinants of speed in classifying visual patterns* (Symposium on Physiological Psychology, ONR Symposium Rep. ACR-1), Pensacola, March.

Hartman, B. O., & Fitts, P. M. Relation of stimulus and response amplitude to tracking performance. *Journal of Experimental Psychology, 49,* 82-92.

Muller, P. F. Jr., Sidorsky, R. C., Slivinske, A J., Alluisi, E. A., & Fitts, P. M. *The symbolic coding of information on cathode ray tubes and similar displays* (Wright Air Development Center, Tech. Rep. 55-375), Wright-Patterson Air Force Base.

Noble, M. E., Fitts, P.M., & Warren, C. E. The frequency response of skilled subjects in a pursuit tracking task. *Journal of Experimental Psychology, 49,* 249-256.

1956

Briggs, G. E., & Fitts, P. M. *Tracking proficiency as a function of visual noise in the feedback loop of a simulated radar fire control system* (Air Force Personnel and Training Research Center, Res. Rep. AFPTRC-TN-56-134), December.

Briggs, G. E., Fitts, P.M., & Bahrick, H. P. *Transfer from a single to a double integral tracking system* (Air Force Personnel and Training Research Center, Res. Rep. AFPTRC-TN56-135), December.

Fitts, P. M., Bennett, W. F., & Bahrick, H. P. Application of autocorrelation and crosscorrelation analysis to the study of tracking behavior. In G. Finch and F. Cameron (Eds.), *Symposium on Air Force human engineering, personnel, and* *training research* (pp. 125-141). Baltimore: Air Research and Development Command.

Fitts, P. M., Weinstein, M., Rappaport, M., Anderson, N., & Leonard, J. A. Stimulus correlates of visual pattern recognition: A probability approach. *Journal of Experimental Psychology, 51, 1-11.*

Harter, G. A., & Fitts, P. M. *The functional simulation of complex systems by means of an analog computer, with the F86D, E-4 system as a specific example. Part l* (Air Force Personnel and Training Research Center, Res. Rep. AFPTRC-TN-56-133), December.

1957

Alluisi, E. A., Muller, P. F., Jr., & Fitts, P. M. An information analysis of verbal and motor responses in a forced-paced serial task. *Journal of Experimental Psychology,* 53, 153-158.

Bahrick, H. P., Fitts, P. M., & Briggs, G. E. Learning curves-facts or artifacts? *Psychological Bulletin, 54,* 256-268.

Briggs, G. E., Bahrick, H. P., & Fitts, P.M. *The influence of force and amplitude cues on learning and performance in a complex tracking task* (Air Force Personnel and Training Research Center, Res. Rep. AFPTRC-TN 57-33), March.

Briggs, G. E., Fitts, P.M., & Bahrick, H. P. Learning and performance in a complex tracking task as a function of visual noise. *Journal of Experimental Psychology, 53, 379-387.*

Schipper, L. M., Kraft, C. L., Smode, A. F., & Fitts, P.M. *The use of displays showing identity versus no-identity: a study in human engineering aspects of air traffic control* (Wright Air Development Center, Tech. Rep. 57-21), Wright-Patterson Air Force Base, February.

1958

Anderson, N. S., & Fitts, P. M. Amount of information gained during brief exposures of numerals and colors. *Journal of Experimental Psychology, 56, 263-*269.

--. Engineering psychology. *Annual Review of Psychology, 9,* 267-294.

Fitts, P.M., Schipper, L., Kidd, J. S., Shelly, M., & Kraft, C. Concepts and methods for the conduct of systems research in a laboratory setting. In G. Finch (Ed.), *Symposium on human engineering, personnel and training research.* (Publication 516, National Academy of Sciences), Washington, D.C.

Kidd, J. S., Shelly, M., Jeantheau, G., & Fitts, P.M. *The effect of en route flow control on terminal system performance* (Wright Air Development Center, Tech. Rep. 57-663), Wright-Patterson Air Force Base, April.

1959

---, (Ed.). *Human engineering concepts and theory.* Ann Arbor: Publications Distribution Service, University of Michigan Press.

---. *Human performance in speeded information processing tasks* (IBM Research Report No. RC-109), April.

---. Visual aspects of engineering psychology. *Psychologia,* 3, 203-225.

1961

---. Skill maintenance under adverse conditions. In *Psychophysiological aspects of space flight* (pp. 309-322). New York: Columbia University Press.

---. Training in engineering psychology. *American Psychologist, 16,* 171-177.

Fitts, P.M., & Jones, R. E. Analysis of factors contributing to 460 "pilot-error" experiences in operating aircraft controls. In H. W. Sinaiko (Ed.), *Selected papers on human factors in the design and use of control systems* (pp. 332-358). New York: Dover Publications.

Fitts, P.M., & Jones, R. E. Psychological aspects of instrument display: I. Analysis of 270 "pilot-error" experiences in reading and interpreting aircraft instruments. In H. W. Sinaiko (Ed.), *Selected papers on human factors in the design and use of control systems* (pp. 359-396). New York: Dover Publications.

1962

Brainard, R. W., Irby, T. S., Fitts, P.M., & Alluisi, E. A. Some variables influencing the rate of gain of information. *Journal of Experimental Psychology,* 63, 105-110.

---. Contributions to a symposium on information processing in the nervous system. In R. W. Gerard and J. W. Duyff (Eds.), *Proceedings of the International Union of Physiological Sciences* (pp. 61-62, 187-190). Amsterdam: Excerpta Medica Foundation.

---. Factors in complex skill training. In R. Glaser (Ed.), *Training research and education* (pp. 77-197). Pittsburgh: University of Pittsburgh Press.

---. Functions of man in complex systems. *Aerospace Engineering,* 21, 34--39.

Fitts, P. M., & Switzer, G. Cognitive aspects of information: I. The familiarity of S-R sets and subsets. *Journal of Experimental Psychology,* 63, 321-329.

1963

--. Engineering psychology. In S. Koch (Ed.), *Psychology, a study of a science* (pp. 908-933). New York: McGraw-Hill, 1963.

Fitts, P.M., Morrison, R., & Members, Life Science Panel, President's Science Advisory Committee, The White House. *Some new technologies and their promise for the life sciences.* Washington: U.S. Government Printing Office.

Fitts, P. M., Peterson, J. R., & Wolpe, G. Cognitive aspects of information processing: II. Adjustment to stimulus redundancy. *Journal of Experimental Psychology,* 65, 423-432.

1964

---. Cognitive factors in information processing. In *Proceedings of the 17th International Congress of Psychology* (pp. 327-329). Amsterdam: North-Holland Publishing.

--. Skill learning. In A. W. Melton (Ed.), *Categories of human learning* (pp. 243-285). New York: Academic Press.

Fitts, P. M., & Peterson, J. R Information capacity of discrete motor responses. *Journal of Experimental Psychology, 67,* 103-112.

1966

———. Cognitive aspects of information processing: III. Set for speed vs. accuracy. *Journal of Experimental Psychology,* 71, 849-857.

Fitts, P.M., & Biederman, I. S-R compatibility and information reduction. *Journal of Experimental Psychology,* 69, 408-412.

Fitts, P.M., & Radford, B. Information capacity of discrete motor responses under dilierent cognitive sets. *Journal of Experimental* Psychology, 71, 475-482.

1967

Fitts, P.M., & Posner, M.I. Human *performance*. Belmont: Wadsworth Publishing Co., Inc. Brookes/Cole.

Jack W. Dunlap, 1902-1977

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Jack Wilbur Dunlap was born in White Eagle, Oklahoma, on the Osage Indian Reservation, on August 11, 1902 and died of cancer in Tucson, Arizona, at the age of 74, on May 8, 1977. He helped develop :human engineering into a technology that can :improve the performance of complex systems of equipment that need human control, supervision, and maintenance. He established Dunlap and Associates, Inc. for the purpose of providing professional human engineering services to gov- ernment and industry; this company grew to be one of the best as well as the largest and best-known organizations to offer such services, and it was soon followed by others. Looking back at his life and times, we can see that Jack W. Dunlap enjoyed three careers: statistician and educational psychologist, Naval officer, and pioneer in human engi- neering. One career led to the others, in substance, as well as in time.

Education and Early Career

Jack Dunlap was the first of the two sons of John W. Dunlap and Abigail E. (Smythe) Dunlap. His father was a station agent for the Missouri Pacific Railroad, and the family was self-sufficient but not affluent. He completed grammar school in Galena and high school in Crane, both in Missouri. While in high school, Jack worked summers as a gandy dancer in a railroad section gang, so named for using tools from the Gandy Manufacturing Company. On his own, he completed a course on bookkeeping. He entered Kansas State Agricultural College (now Kansas State University) in Manhattan in 1919 and majored in agricul-

Jack William Dunlap and Edward W. Bishop, my friends since our early days together at Dunlap and Associates, Inc., provided information and suggestions that are incorporated throughout this memoir. Their assistance is very much appreciated. Jack William Dunlap provided the bibliography and copies of many of his father's publications. Martin A Tolcott and Earl A Alluisi reviewed and made helpful comments on an earlier version of this essay.

tural economics and mathematical statistics. He supported himself by playing the piano in a dance band and enjoyed playing the piano for the rest of his life. He married Hilda H. Frost in 1923, and their only child, Jack William Dunlap, was born in 1924. After receiving a bacca- laureate degree in 1924, Jack Dunlap remained at the college, taught mathematics at the local high schoot and received a Master of Science Degree in 1926. That year, he began doctoral studies at Stanford Univer- sity under Lewis Terman but left in 1927 to become dean of men at the Territorial Normal and Training School in Honolulu. He was head football coach of a team that lost only one game in three years; unfortunately, that happened to be the last game. He served also as principal of Waimanalo Community Schoot a school for grades 1 to 12.

Statistician and Educational Psychologist

In 1930, Jack Dunlap resumed work on his doctorate at Teachers College, Columbia University under Edward L. Thorndike. *His* disserta- tion on "Race Differences in the Organization of Numerical and Verbal Abilities" was published in *Archives of Psychology,* Number 124, at Columbia University in May 1931. His thesis advisers were Henry E. Garrett, Helen M. Walker, and George B. Watson; the editor of *Archives* was Robert S. Woodworth.

The thesis examined differences in numerical ability and verbal abil- ity of Japanese, Chinese, Portuguese, Hawaiian, part-Hawaiian, Ko- rean, and Filipino children between the ages of 10 to 13 in the public schools of Honolulu in the spring of 1927. The purpose of the study was to test a theory that mental ability is an organization of elements or factors. The data that Dunlap analyzed came from the Stanford Achieve- ment Test, Form A, a test that was administered to about 1,950 school children, a total sample of the group he studied. Subtests provided scores on Arithmetic Computation, Arithmetic Reasoning, Paragraph Meaning, Sentence Meaning, and Word Meaning. The reliability of these subtests for ages 10 to 13 ranged from 0.85 to 0.96, with a median reliability of 0.90.

In his thesis, Dunlap tried to answer three questions:

1. What differences in test scores in numerical and verbal material are found among the groups studied? What sex differences are found within these groups?

The Chinese and Korean children had greater mean scores than all other groups in both numerical and verbal material; the Japanese children had greater mean scores only in numerical material. In most groups, females tended to have higher scores than males in tests of verbal material. Two exceptions were the Japanese and Chinese groups, where males had greater mean scores than females in both number and verbal material.

2. Does the group factor for numerical ability found by Truman L. Kelley and others appear in these groups?

Dunlap showed that a number factor appeared in the test scores of all groups. He did this by analyzing the test scores using the tetrad difference technique devised by Carl Spearman.

3. How does the combination of numerical and verbal ability vary from group to group?

The ratio of numerical to verbal ability was higher (larger score for numerical ability) for males among the Japanese, Portuguese, Korean, and Hawaiian children; higher for females among the Chinese; and about the same for the part-Hawaiian children.

In 1932, at the age of 30, Dunlap was appointed Associate Professor of Educational Psychology at Fordham University in New York City and remained there for five years. He was the first non-Catholic Associate Professor at that university. In 1937, he went to the University of Rochester, where he stayed for five years as Associate Professor of Educational Psychology. In 1942, he joined the Navy, with the rank of Lieutenant Commander.

The Territorial Normal and Training School in Honolulu, and particularly the association with Edward (Ted) E. Cureton, was an excellent as well as stimulating start for Jack Dunlap's career. Cureton remained a life-long friend. Dunlap published his first paper in 1930, with Cureton as the senior author. Five more papers with Cureton as coauthor were published that year, a rate of publication he duplicated or surpassed in four other years.

That first paper was a note on how to detect a possible departure from a normal distribution in a sample of test items. The usual method involves use of the chi-square test, which, in those days before computers, involved considerable manual calculation. Cureton and Dunlap proposed using a simpler method, derived from R.A. Fisher's 1925 book on statistical methods. This involves calculating the third and fourth moments about the mean, moments that measure, respectively, asymmetry (or skewness) and kurtosis (or tendency toward peakedness or flat-toppedness). The paper provides a blank form for analysis and instructions for entering data, together with calculated values for the third and fourth moments about the mean. The paper explains how to use a Marchant or Monroe calculating machine and where to read the results on the upper and lower dials.

Dunlap liked to play with numbers and develop short cuts for computation, and he produced several papers of this type in following years: a machine correlation chart (with Cureton, published in 1932); the well-known *Handbook of Statistical Nomographs, Tables and Formulas* (J. W. Dunlap & A K. Kurtz, 1932); a graphical method for computing the standard error of biserial r (with W. J. McNamara, 1934); and nomagraphs for estimating the Spearman-Brown formula (with J. N. Arnold, 1936).

From the first paper he published in 1930 until he entered the U.S. Navy in 1942, Dunlap was the author or coauthor of 42 papers, books, computational charts, or test forms, an average of 3.5 publications a year. These reflect his interests in psychometric methods and the measurement of mental abilities and attitudes. During this period, he was one of the founders of the Psychometric Society and served as its president in 1942. He was an editor of four professional journals: *Journal of Educational Psychology, Journal of Experimental Education, Personnel Journal,* and *Psychometrika.*

Naval Officer

The path of Dunlap's career started to change, imperceptibly at first, in 1940 when he was chosen by the National Research Council to be director of research of the Committee on Selection and Training of Arrcraft Pilots. World War II had started in Europe in September 1939, and the United States began to prepare for war. The production of aircraft, and of many other weapons, increased enormously, and with it the need to select and train pilots. The academic community supported this national effort in many ways, particularly through the National Research Council, an agency of the National Academy of Sciences. Dunlap was an excellent choice for research on the selection and training of pilots because of his expertise and high standing in the professional test and selection community. He served as Director of Research for the Committee for two years while remaining an Associate Professor of Educational Psychology at the University of Rochester. He was also Head of the Freshman Testing Program at Rochester and developed the first university statistics laboratory that was completely equipped with IBM Hollerith (punch card) machines.

A series of research reports appeared as a result of Dunlap's work with the Committee. These include the following:

Tests of the "ability to take it" (1943)

An investigation of the interview
as a technique for selecting aircraft pilots (1944)

Analysis of the Personal History Inventory

(1945) A graphical test for the significance of
differences between frequencies from
different samples (1945)

Analysis of the desire to fly (D-F) inventory (1945)

Collaborators on these papers were J. D. Coakley, D. W. Fiske, F. Gehlmann, J. W. Howland, L. S. Kogan, E. A Lipman, K. J. O'Neil, and M. J. Wantman.

After Jack Dunlap joined the Navy as a Lieutenant Commander in 1942 he was appointed Officer-in-Charge, Aviation Free Gunnery Training and Research Unit at the Naval AIT Station, Boca Chica, Florida, near Key West. "Free gunnery" refers to guns that are mounted in various locations on large bomber and patrol aircraft ansi used for protection against attacking enemy aircraft. At other times, Dunlap was stationed at Naval AIT Stations in Purcell, Oklahoma, and Jacksonville, Florida; in the Navy Department in Washington, D.C.; and, when the war in Europe ended, on a special assignment with the Office of Naval Intelligence in the European Theatre of Operations. We know of only three reports that Dunlap prepared during his service in the Navy: an evaluation report on the Mark 18 gunsight (1944), a briefing on methodology employed in testing aircraft gunsights (1944), and a description of devices the Germans used to train operators of several types of guided missiles (1945).

In Europe, Dunlap was a member of the U.S. Naval Technical Mission in Europe, a team given the mission to capture as much information as possible from the Germans about their new technological developments before our Russian allies could do the same thing. This was Project Paperclip, a highly classified intelligence mission about which little was known until many years later. I had also been in the Navy during the war, and, on several occasions, Jack Dunlap told me, in sketchy terms, something about his work on Project Paperclip. He described it as a race against the Russians. Paperclip looked for equipment, documents, facilities, and, above all, for the scientists who developed new weapons with which the Germans hoped to win the war. Scientists who were found were returned to the United States for further interrogation. When I asked Dunlap's son, Jack William Dunlap, what he might know about Paperclip, he provided the following information in a letter dated December 23, 1991:

> Regarding "Paper Clip"; YES! Jack did mention it and in fact I participated in it with him! Though he never mentioned the Code Name and I didn't know what I was doing. This is what happened:

- In May 1945 my Division HQ (104th Inf. Div.) was at Halle, about 25 miles Northwest of Leipzig.
- Part of Jack's mission (so I was told years later) was to pick-up the Engineering Staff and Drawings for the ME 262 [a new jet aircraft].
- In Halle Jack arranged for me, ,thru my Division C.G. (Major General Terry Allen), 3 or 4 days Detached Duty as his armed escort to Leipzig. Jack was accompanied by a junior Naval Officer.
- At the Leipzig Airport we searched a number of "abandoned" buildings… ME FIRST! As I only had an M-1 Rifle, I was very uncomfortable in those narrow hallways and staircases.
- Anyway, we met some people and Jack and the other Officer made some arrangements with them… I was not privy to the discussions.
- Jack then took me back to my Division in Halle.
- Years later, he told me that the following week he had 1 or 2 DC-3's land in Leipzig to pick-up the key Staff and their families for transport to Paris… from there who knows… end of story… almost.
- Jack spent another several months in Germany, after that, in the northern sector near Hamburg & Kiel… what he was doing and where he went… God knows… he never told me. I do know he had about 100 cartons of Cigarettes my Squad had given him… for trading purposes and that he made good use of them.[1]

Human Engineering

Jack Dunlap left the Navy as a captain in 1946. In the spring of that year, he joined The Psychological Corporation in New York City and received the support of George Bennett, its president, *to* establish a new Division of Bio-Mechanics. Rather than return *to* an academic career, Dunlap had decided *to* start a professional organization that would develop and use scientific information about human capabilities *to* improve the performance of complex equipment, systems, and organizations. The focus would be on human engineering, defined broadly to include not only human factors in the design of equipment, but also in military systems and industrial organizations.[2] As it turned out, Dunlap

1. Neither the ME 262 nor Jack W. Dunlap are mentioned in Linda Hunt's *Secret Agenda* (New York: St. Martin's Press, 1991), a book that describes activities of the U.S. government, Nazi scientists, and Project Paperclip over the period from 1945 to 1990.

2. Earl A. Alluisi pointed out to me that Edward L. Thorndike, Dunlap's thesis adviser at Columbia, used the term *human engineering* in his report on what psychologists had done during World War I: "The secret of success in applied psychology or human engineering is to be rigorously scientific. ... Making psychology for business or industry or the army is harder than making psychology for other psychologists, and intrinsically requires higher talents.... Psychology applied to the complicated problems of personnel work represents scientific research of the most subtle, involved and laborious type" (60). See Edward L. Thorndike, "Scientific Personnel Work in the Army," *Science* 49 (1919): 53--61.

was the first to start a company for the purpose of providing human engineering services. He selected the name *Bio-Mechanics to* emphasize his focus on the man-machine interface in complex systems. The term *human engineering,* although acceptable, had been used previously to describe human relations and social aspects of industrial production processes.[3]

The Bio-Mechanics Division opened its doors for work in August 1946 and, within six months, Dunlap recruited Ralph C. Channell, John D. Coakley, Joseph Gallagher, Martin A Tolcott, and me. Gallagher was an accountant; the rest of us were psychologists. Four of us had served in uniform during the war and, like Dunlap, were experienced in military operations, training, and training devices. This grovp shared Dunlap's vision that professional attention *to* human factors in the design of complex equipment could improve the effectiveness of military operations and of industrial organizations and that the idea of starting a company to provide such services on a commercial basis was a risk worth taking. When Dunlap spoke about this, which was often and to anyone who would listen, it was also an adventure and a challenge. He placed particular emphasis on the need *to* provide high-quality, first-rate professional services.

At about this time, the Navy established the Special Devices Center at Sands Point, Port Washington, Long Island, as a part of the Office of Naval Research. This was easily accessible from New York City. The buildings and grounds of the new center were on a large estate, once owned by Harry Guggenheim, that overlooked Long Island Sound. An elegant stone mansion became an office building, and a large stone stable was turned into a shop and support facility.

The Office of Special Devices had been led during the war by Rear Admiral Luis de Florez, USNR, an impressive and imaginative reserve officer. His group developed many innovative training devices, booklets, and movies designed to improve military training. This activity was so effective and appreciated by the Navy that it was continued and enlarged after the war to include a research capability in human engineering. The first director of the Human Engineering Division in the new Special Devices Center was Leonard C. Mead, who moved later to Tufts University, became Director of its Institute for Applied Experimental Psychology, and served as Vice President of the University. Clifford P. Seitz, James J. Regan, Vincent J. Sharkey, and Harold A Voss

3. See, for example, C. R. Gow, *Foundations for Human Engineering* (New York: Macmillan, 1930);" and F. A. Magoun, *Problems in Human Engineering* (New York: Macmillan, 1932).

soon joined the Human Engineering Division. When the Special Devices Center moved to Orlando, Florida and became the Naval Training Systems Center, the main building was named after Admiral de Florez.

The first contract that the Division of Bio-Mechanics received was one from the Human Engineering Division of the Special Devices Center in 1946 to prepare a series of studies dealing with human factors in high-speed flight; at that time, high-speed was 350 miles an hour, and high altitude was 35,000 feet. The purpose of this contract was to summarize significant information about human capabilities in the psychological and physiological research literature in such areas as vision, audition, vibration, and manual dexterity so that it could be used to improve the design of the displays, controls, and working environments that affected the performance of operators and maintainers of aircraft, ships, and other military weapons. This contract produced a series of papers that provided the basis, together with work supplied by other contractors, for the first handbooks of human engineering design prepared by Tufts University (1952), by Woodson and Conover (1954), by Morgan, Chapanis, Cook, and Lund (1963), and by others in following years.

Many of the issues dealt with in these papers had been recognized by psychologists when they served during World War II and are reported in the 20-volume set with the title *Army Air Force Psychology Program Report* published by the Government Printing Office. Of these, the most relevant to the work of Dunlap and his colleagues was the volume edited by Paul M. Fitts, *Psychological Research on Equipment Design* (Report Number 19, 1947). Paul Fitts, Walter Grether, Alphonse Chapanis, William E. Kappauf, Franklin V Taylor, Arnold Small, Arthur Melton, John Flanagan, Alexander Williams, George A. Miller, Launor Carter, Carl Pfaffman, Ross McFarland, Charles W. Bray, Karl Kryter, J. C. R. Licklider, and many others had been engaged in developing and using human factors engineering as a discipline in various military activities, or in a service laboratory, or at a university. Prominent among the issues they examined were the effects of high-altitude and high-speed flight on human performance, night vision, dark adaptation, legibility of instruments, intelligibility of radio communications, and the compatibility between various types of control mechanisms and visual displays. Some of these key personnel remained in service laboratories when the war ended, whereas others returned to academic careers. Human engineering was being developed in many places at the same time. Work started in the Division of Bio-Mechanics at The Psychological Corporation before the Fitts volume was published.

Dunlap and his entire group (except for Joseph Gallagher) left The

Psychological Corporation in 1947 and established Dunlap, Morris and Associates, Inc. in New York City; in 1950 the name of the company was changed to Dunlap and Associates Inc., when the group moved to Stamford, Connecticut. Continued support by the Special Devices Center, the Office of Naval Research, the Air Force, and the Army made it possible for Dunlap and his colleagues to make significant contributions to our understanding and use of human factors technology. Only some of the early contributions are noted here; the work soon extended into other areas that will also be discussed:

An analysis of pilot's performance in multi-engine aircraft (R5D) (1947)
An evaluation of the effects of acceleration on the control and safety of high-speed aircraft (1948)
Effect of heat on the performance of men in high-speed aircraft (1948)
Estimates of visibility from high-altitude aircraft (1948)
The human factor in the design of stick and rudder controls for aircraft (1948)
Arrangement of equipment in a submarine combat information center (1948)
Evaluation of the Bausch and Lomb fixed-eyepiece periscope (1949)
The relative legibility of black and white figures for instrument dials (1949)
illumination in the attack center and periscope area of the SS 563/564 (1949)
Human factors in the design of the submarine control room (1949)
Human factors in the design of airships (1950)
Human factors in the design of submarine communications systems (1950)
Visual requirements for a wheels-up warning signal device on an aircraft (1950)

These papers fall in two groups: one that summarizes human capabilities in selected areas (e.g., effect of heat on human performance, relative legibility of black and white figures, visibility from high altitude, effects of acceleration on the control and safety of high-speed aircraft) and another that applies human engineering information to the design of specific equipment (e.g., the human factor in the design of stick and rudder controls of aircraft, arrangement of equipment in a submarine combat information center, human factors in the design of airships, the submarine control room, submarine communication systems, and so on).

From the very beginning, Dunlap and his colleagues were also able to undertake significant and relatively large-scale efforts in human engineering for industry; this enlarged their knowledge and supplemented their work for the military services. Two early examples occurred at The Psychological Corporation, and both involved quality control of manufacturing processes. The first study concerned the production of nylon stockings, a product for which there was a high demand and that had a high value immediately after the war. The president of Massachusetts Knitting Mills, Inc. believed that the number of stockings being produced in his three mills was much less than what he expected from the amount of nylon thread that was supplied. He suspected thievery. The Dunlap group developed a flow diagram of the entire production process. They measured and weighed the amount of yam delivered, the amount of waste produced by the knitting machines, and the amount of yam in defective stockings and in various stages after knitting, such as boarding, shaping, and packing the stockings. John Coakley was able to show that there was about 30% variation in the dry, clean weight of stockings intended to be of the same size but produced by different operators working on the same machine. The group found that variances in the weights of yam input and output, including captured waste, were in reasonably close tolerance and that it was unlikely that any appreciable amount of thievery was taking place. The client did not like the results of this investigation, and his lack of appreciation was a rude shock to a group of serious (and perhaps naive) scientists with advanced academic degrees.

The second key study was conducted, in a more amiable environment, for the Eli Lilly Company, a family-owned ethical drug company with a very high standard for the quality of its product. The company was interested in a human factors review of its operations to identify opportunities for reducing the possibility of error in the production of drugs. Dunlap and his colleagues made a thorough investigation of all stages of the manufacturing process and pointed out ways of introducing automation, in selected areas, that could reduce the potential for human error. Some of the recommendations were implemented; others had merit but because they would replace long-term employees were not adopted. This was truly an instance where personal responsibility for others was a company policy even though it might reduce profits. This was possible because of the family-owned nature of the company.

In 1952, the Panel on Human Engineering, Committee on Human Resources, Research and Development Board of the Department of Defense recommended that the three branches of the Armed Services jointly develop the *Human Engineering Guide to Equipment Design.* This guide was published by McGraw-Hill Book Company, Inc. in 1963; the editors were Clifford T. Morgan, JesseS. Cook, Alphonse Chapanis, and

Max W. Lund. The Steering Committee consisted of Walter F. Grether, Franklin V. Taylor, Lynn E. Baker, Clifford P. Seitz, Alphonse Chapanis, and Henry A Imus, with Arnold M. Small as chair.

The Behavioral Science Laboratory of the Air Force Systems Command at Wright-Patterson Air Force Base, Dayton, Ohio, with Walter F. Grether as Technical Director, commissioned Dunlap and Associates, Inc., to prepare a number of technical reports that became chapters on the following topics in the *Guide:*

1. Man-machine dynamics
2. Design of controls
3. Layout of workplaces
4. Arrangement of groups of men and machines

Members of the Dunlap staff who prepared these chapters during the period from 1956 to 1958 were Hugh M. Bowen, Bernard J. Covner, Jerome H. Ely, Herbert H. Jacobs, Robert M. Thomson, and L Some of this work was also supported by the Office of Naval Research. These reports extended the breadth and scope of human engineering technology that had been initiated by the Special Devices Center.

As a professional organization, Dunlap and his colleagues were able to extend their efforts far beyond the area of human engineering. Jack Dunlap was a key adviser to the Navy's Polaris Program, a high-priority strategic program directed by Admiral William Raborn, USN, on whose staff Dunlap had served during the war. Dunlap and Associ- ates, Inc. was closely involved in the analysis and design efforts needed to identify the role of human operators in this complex and important system. Later, Admiral Raborn became Director of the Central Intelligence Agency.

An unusual study was an operations research analysis concerning the most productive use of large draglines in strip mining of phosphates. The key factors that influenced productivity in this type of surface mining were found to be the depth of the overburden (covering soil), depth of the phosphate layer, width of swing of the dragline, and location of the drop areas for initial processing of the phosphate. Herbert H. Jacobs, who collaborated with Jack Dunlap on this study for the International Minerals and Chemicals Corporation in 1955, developed a computer model that was run on the new Whirlwind computer at MIT during whatever time he could get access to the computer, usually late at night during weekends. Dunlap was, of course, familiar with IBM office-type computing equipment, but this was the first exposure of his group to one of the most advanced computers.

Dunlap developed a close relationship with the Armed Forces Epidemiological Board and participated in a long series of studies on personal factors in accident causation. Some of these involved field experiments to collect data on the effect of measures taken to promote safety, for example, how well and for how long people reacted positively to new signs on safety, to newly painted lines on roads to direct automobile traffic, to reduced driving speed when police were stationed in patrol cars by the side of the road, or to damaged automobiles left within sight of motorists.

At various times, empirical work was done on the design of flight maps to improve the navigation of aircraft, with different markings for visibility by day and night illumination; on the size and text of signs used to direct aircraft traffic on airfields, (experimental work was done on the runways at Idlewild Airport, before it became J. F. Kennedy International Airport, to confirm data collected in laboratory tests); on how rumors spread (done experimentally on submarines by planting statements that could be tracked); and on many weapons (e.g., Thor, T-33, Stinger, CF-105 aircraft, and airborne early warning aircraft). This was interspersed with industrial work such as that on checkers and the design of check-out stations in supermarkets for the Great Atlantic and Pacific Tea Company in New York and Pennsylvania and for Stop and Shop in Massachusetts; on the selection of sales staff for the Amity Leather Products Company; on charts for the Bristol Company; and on color television for the Columbia Broadcasting System, Inc.

Jack Dunlap continually emphasized the importance of delivering an excellent product and of the responsibility that his associates had as members of a professional organization. He tried to recruit highly qualified personnel and paid higher than average salaries to attract and keep competent individuals. Technical reports were reviewed before they were delivered and modified if they were judged to be incomplete or inadequate. This was sometimes done at the expense of Dunlap and Associates rather than of the client. Considerable effort was given to maintaining a professional atmosphere in the organization, and there was little turnover among the staff. The excellent reputation enjoyed by Dunlap and Associates, Inc., was the direct result of the way Jack Dunlap set the professional standard for his associates. He was able to recruit many outstanding individuals, such as Joseph E. Barmack, Hugh M. Bowen, Robert L. Chapman, Robert T. Eckenrode, Jerome H. Ely, Edward Girden, Herbert H. Jacobs, Charles R. Kelley, David B. Learner, Norman H. Mackworth, Martin A. Tolcott, Joseph Wohl, Joseph W. Wulfeck, and Kenneth W. Yarnold.[4]

4. Leon Festinger, well known later for his work on cognitive dissonance, worked as a consultant and was coauthor of a paper on estimates of visibility from high-altitude aircraft; a coauthor of that paper was Harold H. Kelley, well known for his work in social psychology. Paul M. Fitts served as an occasional consultant. I am sorry to say that half of these friends I have cited here have died.

Entrepreneur

The story of Jack Dunlap's life would be incomplete without considering his career as an entrepreneur and businessman, almost always with human engineering emphasis. This shows explicitly in the establishment of the Division of Bio-Mechanics at The Psychological Corporation in 1946, and of Dunlap, Morris and Associates, Inc. in 1947. Philip Morris was a close friend and colleague when he and Dunlap were Naval officers. Morris gave up consulting work and returned to his family's business (Pabst Brewing Company) in 1950. Then, the name of the company was changed to Dunlap and Associates, Inc. when it moved to Stamford, Connecticut; the company moved again, in 1963, to its own building in Darien, Connecticut.

Dunlap and Associates, Inc. was a successful business as well as a respected professional venture. Dunlap's division in The Psychological Corporation had about 10 employees; Dunlap, Morris and Associates, Inc. started with about 30 employees; at its peak in 1965, Dunlap and Associates, Inc. had about 150 employees and sales of about $5.5 million; an additional 25 employees worked at a branch office in Santa Monica, California, led by Joseph W. Wulfeck. Dunlap and Associates, Inc. also established several subsidiary organizations to perform certain services:

Clark Channell, Inc., 1956
- psychological testing for industry

Dunlap and Associates of Canada, Inc., 1957
- human engineering, industrial consulting

Public Service Research Institute, 1958
- research grant activities for the Department of Health, Education and Welfare

Clark, Cooper, Field and Wohl, Inc., 1962
- operations research, psychological testing, executive search
- Clark Channell, Inc. was merged into this group

Agri Research, Inc., 1962
- agricultural research in developing countries

Uni-Consult, 1965
- acquired by Agri Research, Inc.

- Dunlap and Associates, Inc. became a general partner in Olive Seed & Oil Partnership

Jack Dunlap retired as President of Dunlap and Associates, Inc. in 1968 but remained active as Chair of the Board. Ralph C. Channell, previously Executive Vice President, became President, and Jack William Dunlap became the Executive Vice President. When Ralph Channell retired in 1969, Jack William Dunlap became Chair and President. In 1973, Dunlap and Associates, Inc. acquired Reflectone, Inc., from the Otis Elevator Company. Reflectone developed training devices for the military services, but it did not fit well in the Otis organization. Reflectone grew rapidly, and total sales exceeded $32 million by 1982.

Entrepreneurship may be more glamorous in retrospect than in actual practice. The trajectory of Dunlap's business ventures tended to rise, but not without some bumps. There were times, in the early years, when there were insufficient funds to support the entire staff. Jack Dunlap was a responsible leader and contributed some of his personal funds to pay the salaries of the junior staff while some of the senior staff went on reduced salaries. Some of the adjunct companies were closed because of insufficient business; two of these companies were sold to their employees.

Reflectone, Inc. was more of a success than Dunlap and Associates, Inc. needed. It grew rapidly, and with it came the need for more capital. A secondary public stock offering in 1980 not only raised additional capital but also made it possible for other entrepreneurs to assume control. The name of the corporation was changed to Reflectone, Inc., and the Dunlap and Associates, Inc. segments became divisions of the larger company. Ultimately, these divisions were able to buy out their own assets and become independent companies, called Dunlap and Associates, Inc. East and Dunlap and Associates, Inc. West. Reflectone, Inc. was acquired in 1973 after Jack Dunlap retired but while he was still alive. The dominance of Reflectone, Inc. over Dunlap and Associates, Inc. occurred in 1982, after Jack Dunlap died. Dunlap and Associates, Inc. still exists as a relatively small consulting organization in Norwalk, Connecticut.

Jack Dunlap's role as an entrepreneur was always supportive and warm, and he collaborated easily and closely with his associates. These associates were encouraged to acquire stock and participate in management and ownership-on very favorable financial terms. Dunlap is known to have paid a new employee a larger salary than had been agreed to at the time of hiring. His reason-so he would know that he was appreciated and work harder.

In addition to work for his own company, Jack Dunlap also served on the Board of Directors of other business organizations:

International Minerals and Chemicals Corporation
Hamar Laser Instruments, Inc.
Industry Data Systems
Rixon Electronics, Inc.
Management Council of Southwestern Connecticut
The Witt Company
Chart Pak, Inc.
Pioneer Medical, Inc.
Development Research and Planning Associates, Inc.

Jack Dunlap was active in 17 professional societies and was a Fellow of the American Psychological Association and of the Human Factors Society. He was a Diplomate in Industrial Psychology of the American Board of Examiners on Professional Psychology. He was a founder of the Psychometric Society and its President in 1942; he was also a founder of the Human Factors Society and its President in 1961. He was President of the New York State Association of Psychology and of three divisions of the American Psychological Association: Consulting Psychology (1947), Industrial and Business Psychology (1950), and Military Psychology (1955). His alma mater, Kansas State University, conferred the honorary LL.D. degree in 1960.

Dunlap is in good company in these pages. He knew all of the distinguished members of the Division of Applied Experimental and Engineering Psychologists who are honored in this volume. Paul M. Fitts was one of his students and served as a consultant to Dunlap and Associates, Inc. Jerome H. Ely was one of the bright young stars of Dunlap and Associates, Inc. Once, when Franklin V Taylor visited Stamford, Dunlap tried to hire him. Most of the others were close friends and colleagues. MartinA Tolcott and I were members of Dunlap and Associates, Inc.

The nature of Jack W. Dunlap may be summarized, in addition to his accomplishments, in purely personal terms. His recreational interests included ping-pong, piano, bridge, golf, poker, chess, lapidary work, fishing, magic, and helping small minority businesses get started. His philosophy of life in his own words from "Concepts I have found useful" include:

- A man should kill his own snakes
- Solve your own problems, don’t run crying for help to others
- Pray the good Lord for guidance, but work like hell.
- Always have confidence in yourself and keep on plugging.

- Always give a little more than expected.
- Be humble, you really know very, very little, and others know more than you.
- We can't change the past, but we may have some effect on tomorrow.
- A man without principles is at the mercy of whims and vagaries of others.
- In any deal, take a little and leave a lot.
- Double first that of which you are sure.

Publications of Jack W. Dunlap

Except where noted, Jack W. Dunlap is the sole author of the publication listed.

1930

Cureton, E. E., & Dunlap, J. W. Note on the testing of departure from normality. *Journal of Applied Psychology, 19,* 91.

Cureton, E. E., & Dunlap, J. W. Scoring the rearrangement or continuity test. *School Review, 38,613.*

Cureton, E. E., & Dunlap, J. W. Some effects of heterogeneity of the theory of factors. *American Journal of Psychology, 42,* 608-620.

Cureton, E. E., & Dunlap, J. W. Spearman's correction for attenuation and its probable error. *American Journal of Psychology,* 42,235.

Dunlap, J. W., & Cureton, E. E. On the analysis of causation. *Journal of Educational Psychology,* December, 657.

Smith, M. E., Lecker, G., Dunlap, J. W., & Cureton, E. E. The effects of race, sex, and environment on the age at which children walk. *Pedagogical Seminary and Journal of Genetic Psychology,* 38,489-498.

1931

———. Race differences in the organization of numerical and verbal abilities. *Archives of Psychology* (124).

1932

Cureton, E. E., & Dunlap, J. W. C-D *machine correlation chart.* New York: Macmillan.

---. Fallible scores and the standard error of a difference. *American Journal of Psychology,* 44,581.

———. The organization of learning and other traits in chickens. *Comparative Psychology Monographs* 9(4). Baltimore: Johns Hopkins University Press.

Dunlap, J. W., & Kurtz, A. K *Handbook of statistical nomographs, tables, and formulas.* Yonkers: World Book Company.

1933

---. Comparable Tests and Reliability. *Journal of Educational Psychology,* September, 442.

1934

McNamara, W. L & Dunlap, J. W. A graphical method for computing the standard error of biserial r. *Journal of Experimental Education,* 2(3}.

1935

———. The predictive value of interest test items for achievement in various school subjects. *Journal of Applied Psychology,* 9(1), 53-58.

———. Preferences as indicators of specific academic achievement. *Journal of Educational Psychology,* September, 411.

1936

Arnold, J. N., & Dunlap, J. W. Nomographs concerning the Spearman-Brown formula and related functions. *Journal of Educational Psychology,* May, 371.

———. Note on computation of bi-serial correlations in item evaluation. *Psychometrika,* 1(2), 51.

———. Relationships between constancy of expressed preferences and certain other factors. *Journal of Educational Psychology,* May, 521.

1937

---. Combinative properties of correlation coefficients. *Journal of Experimental Education,* March, 286.

———. *Dunlap academic preference blank.* Yonkers: World Book Company [Test: Form A and Form B].

Voss, H. A., & Dunlap, J. W. Determination of the Heinis personal constant. *Journal of Consulting Psychology,* 1(4), 57-61.

1938

———. An abac for determining the mean deviation of a class from the general mean. [Source unknown.]

---. Recent advances in statistical theory and applications. *American Journal of Psychology,* 51(3), 558-571.

---. The relationship between the type of question and scoring errors. *Journal of Experimental Education,* March, 376.

---. To test or not to test. *Summer Session News,* 1(3), University of Rochester.

1939

———. Suggestions as to library tools and techniques. Prepared for the Department of Education, University of Rochester.

———. *Workbook in statistical method.* New York: Prentice-HalL

Dunlap, J. W., & Kroll, A. Observations on the methodology in attitude scales. *Journal of Social Psychology, 10,* 475-487.

1940

---. Applications of analysis of variance to educational problems. *Journal of Educational Research,* February, 434.

---. The efficient direction of human resources in college. *Summer Session News,* 3(1), University of Rochester.

---. Note on the computation of tetrachoric correlation. *Psychometrika,* 5(2), 137.

---. Problems arising from the use of a separate answer sheet. *Journal of Psychology,* 10, 3-48.

---. Self-counseling for the college student. *Journal of Higher Education,* 11(9), 486-489.

Sharkey, V J., & Dunlap, J. W. Study of the reliability and validity of the academic preference blank. *Journal of Educational Psychology,* February, 103.

1941

---. Recent advances in statistical theory and applications. [Source Unknown.]

Peterson, B. M., & Dunlap, J. W. A simplified method for scoring the Strong Vocational Interest Blank. *Journal of Consulting Psychology,* 5(6), 269-274.

1942

---. Evaluation of data in a personnel program. *Journal of the American Association of Collegiate Registrars,* July, 493.

---. The Psychometric Society-Roots and powers. *Psychometrika,* 7(1), 1.

---. Regarding flow control of quality and quantity of naval aviation cadets. Briefing/tech memo presented to Admiral Radford, USN and Capt. Wicks, USN.

Harper, B. P., & Dunlap, J. W. Derivation and application of a unit scoring system for the Strong Vocational Interest Blank for women. *Psychometrika,* 7(4), 289.

1943

Dunlap, J.W., Howland, J. W., Coakley, J. D., Lipman, E.A., Gehlmann, F., O'Neil, K.J., & Kogan, L. S. *Tests of the "ability to take it"* (Civil Aeronautics Administration, Division of Research, Report No. 11). Restricted, not for publication.

1944

---. Report on the MK 18 gunsight, evaluation project at Boca Chica, Fla., B31126N. Confidential, October.

--. Methodology employed in testing aircraft gunsights. Briefing/speech, October.

Dunlap, J. W., & Wantman, M. J. *An investigation of the interview as a technique for selecting aircraft pilots* (Civil Aeronautics Administration, Airman Development Division, Report No. 33), August.

1945

---. *Trainers for operators of guided missiles* (Technical Report No. 229-45, US Naval Technical Mission in Europe, AD A953 443).

Fiske, D. W., & Dunlap, J. W. A graphical test for the significance of differences between frequencies from different samples. *Psychometrika,* 10(3), 225. Kogan,

L. S., Wantman, M. J., & Dunlap, J. W. *Analysis of the desire to fly (D-F) inventory* (Civil Aeronautics Administration, Division of Research, Report No. 50).

Kogan, L. S., Wantman, M. J., & Dunlap, J. W. *Analysis of the personal history Inventory* (Civil Aeronautics Administration, Division of Research, Report No. 42).

1946

---. The human factor in product design. *Management Review,* American Management Association, September.

1947

---. Men and machines. Presidential address, Division of Consulting Psychology, 55th annual meeting, American Psychological Association, September.

---. Men and machines. *Journal of Applied Psychology,* 31(6), 565.

1948

Coakley, J.D., Tolcott, M.A., & Dunlap, J. W. Applied research as illustrated in Project Therblig. Presented to Research and Development Board, Committee on Human Resources, Panel on Human Engineering and Psychophysiology. November. Confidentialr November.

---. Selection of enlisted airmen. Presented to the 19th annual meeting, Aero Medical Association, Toronto, June.

---. Vocational guidance. Presented to the Vocational Guidance Department, Teachers College, Columbia University, May.

1950

---. Bio-mechanics. In Douglas H. Fryer & Edwin R. Henry (Eds.), *Handbook of applied psychology.* New York: Rinehart.

---. The management of morale. *Personnel Psychology,* 3(3), 353-359.

1951

---. The master: Man or robot? Presidential address, Division of Industrial and Business Psychology, American Psychological Association, August.

---. Morale surveys for small business. Presented to American Psychological Association, September.

1952

---. The human engineer: New ally for the electrical engineer. *Electrical Engineering,* February, 107.

---.Morale surveys. *Personnel Psychology,* 5(1), 35-39.
---.Why not consider human capabilities and limitations when we design machines? Presented to American Association for the Advancement of Science Symposium on Men and Machines, St. Louis, December.

1953

---. Human engineering: What it is and what it can do for you. In *Factory management and maintenance.* New York: McGraw-Hill, January.

1954

---. Current methods and future needs in selecting aviation personneL Presented to 22nd annual meeting of the Institute of Aeronautical Sciences, January.
---.Evaluation of training (is training worth-while?). Presented to Training Officers Conference, Washington, D.C., January.
---. Human engineering applied to machine design. Presented to 18th annual National Time and Motion Study and Management Clinic of the Industrial Management Society, Chicago, November.
---. Operations research accomplishments on production problems. Presented to 5th annual Industrial Engineering and Management Conference, Montreal, March..
---. Operations research: A practical tool for management. *Manufacturing and Industrial Engineering,* July.
---. Psychologists and the cold war. :Presented to the Division of Military Psychology, American Psychological Association, September.
---. Science and the cigar industry's future. Presented to the CMA-CAI Convention, Atlantic City, December.
---. The selection of an operations research staff. Presented to Operations Research Council, January.
---. The sensitive adjustment of men to machines. *Army Combat Forces Journal,* October.
---. Subjective design. *Electronic Design,* October, 30.
---. To be or not to be. Presidential address, Division of Military Psychologists, American Psychological Association, September.
---. Would operations research help in your company? *N.A.C.A. Bulletin,* October, 242-250.
Dunlap, J. W., & Wheeler, D. Human engineering applied to machine design. National Time and Motion Study and Management Clinic of the Industrial Management Society, Chicago, November.

1955

---.Applications of operations research to operating problems in the mining industry, IL In *What is operations research accomplishing in industry?* Sponsored by the Operations Research Group, Engineering Administration Department, Case Institute of Technology, ApriL

---. Engineering products to fit the user. Presented to the Canadian Industrial Management Association, Toronto, November.
---. [circa 1955]. Human factors in industrial design. Society for Advancement of Management, New York City.
---.Psychologists and the cold war. *American Psychologist, 10(3),* 107-109. Dunlap, J. W, & Jacobs, H. M. Strip mining phosphate rock *Journal of the Operations Research Society of America,* 3(1), 20-33.
Dunlap, J. W., & Ware, T M. Application of operations research to operating problems in the mining industry. In *What is operations research accomplishing in industry?* Sponsored by the Operations Research Group, Engineering Administration Department, Case Institute of Technology.
Dunlap, J. W., & Ware, T M. They harnessed the dragline. *Operations Research Digest,* October, 3-5.

1956

Cooper, G., & Dunlap, J. W. The role of a staff in decision-making. Presented to the 1956 Operations Research conference, Society for the Advancement of Management, New York City, November.
---. Human Engineering: Another management tooL Presented to the 4th annual Social Science for Industry Meeting, Stanford Research Institute, San Francisco, ApriL
---. Research in operations-A new management philosophy. Presented to the 17th annual Mining Symposium, University of Minnesota, Duluth, January.

1957

---. An address on accident research. Presented to the 25th annual meeting of the American Bridge, Tunnel and Turnpike Association, Chicago, October.
---.Needs and developments in equipment and technology. Presented to Division 14 of the American Psychological Association, New York City, September.
---.Report on accident studies supported by the Commission on Accidental Trauma of the Armed Forces Epidemiological Board. Presented to The President's Committee for Traffic Safety, Washington, May

1958

---. Remarks on accident research needs. [Probably presented to the Commission on Accidental Trauma], ApriL

1959

[An address; no title]. Presented to the American Society of Safety Engineers, New York City, ApriL
---. Needs and developments in equipment and technology. *Personnel Psychology,* 12(1), 34-36.

———. Operations Research-A Tool of Management. Presented to AMA, Unit 1 Management Course, New York City, September.

1960

———. Homo-researchiens, the care and feeding of. Presented to the Seminar on Research Planning and Management, Naval Reserve Research Company 4-1, Office of Naval Research, Princeton, August.

———. Psychometrics: A special case of the Brahman theory. Presented to the 25th annual meeting of the Psychometric Society, Chicago, September.

———. Research scientist: The care and feeding of. Presented to the American Mining Congress, Las Vegas, October.

1961

---. Professional relationships with clients. Presented to Division 14, Industrial Psychology Meeting, American Psychological Association, September.

---. You, the pioneers. Presented to the annual meeting of the Chamber of Commerce, Manhattan, Kansas, January.

1962

---. Growth by design. Presented at the dedication dinner of Agri Research's new building, Manhattan, Kansas, May.

1963

---. New dimensions in management consulting. Presented to the Commerce Alumni Conference, Kansas State University, Manhattan, October.

Dallenbach, K. M. A pain-scale: A report from a victim of tic douloureaux. American Journal of Psychology, 76(1), 152-155. [Written by Dunlap but not prepared for publication; sent to Dallenbach as information only, who thought it should be published anonymously over his authorship.]

1964

---. The psychologist in industry: Pleasures and pitfalls. Presented to the Psychology in Management Seminar, Purdue University, April.

1967

---. Dunlap and Associates-A new way of thinking about problems. County, September.

---. The impact of acceleration on mankind. Presented to the Rotary Club, Stamford, Connecticut, November.

1968

---. Support services by independent research groups. Presented to the annual membership meeting, American Mining Congress, Washington, January.

1969

———. Operations abroad. Presented to the International Executive Association., March.

1970

———. Prospects for software research consulting. Prepared for H. Graham Smith for the *0-T-C Chronicle,* January.

Alexander Coxe Williams, Jr., 1914-1962

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The brilliant, foreshortened career of the father of the Illinozs school of aviation psychology.

Alexander Coxe Williams, Jr., was a gentleman and a scholar. In the small, cozy world of aviation psychology, he is best remembered for his students who pioneered the burgeoning field of human engineering in the aerospace industry starting in the 1950s. However, it was his own ideas, research, and inventions that gained him international recognition during the brief span of 16 years between 1946 and his fatal heart attack in 1962 at the age of 48. Less than a year had passed since he was honored with the first annual Franklin V Taylor career award by the American Psychological Association's Society of Engineering Psychologists.

In those exciting years following World War II, Alex Williams was recognized by his peers before all others in the field of engineering psychology. During those heydays of the specialized subfield of aviation psychology, Alex was in the vanguard of research and application of the human factors in flight display system design and the quantitative measurement of the transfer of training in flight simulators to pilot performance in airplanes. Still, he is less well known today than some of his disciples who invaded the aerospace industry during the 1950s and later academia and spread his gospel over the next four decades.

The Early Years

Alex Williams was born in Philadelphia and raised in Wilkes-Barre, Pennsylvania. As a child he was a prodigious chess player, often playing games with several adults simultaneously. With his adversaries seated in a circle facing inward, Alex would proceed from one board to the next, quickly assess and counter the opponent's last move, then move on to the next situation. He rarely lost and, during his college

years, never lost a golf match. Tied after 18 holes in his senior year, he made the only hole-in-one of his life to avert imminent defeat in sudden-death match play for his fourth consecutive conference championship.

Alexander C. Williams, Sr., was a prominent engineer in industrial Wilkes-Barre. Despite a childhood fascination with gadgetry, Alex, Jr., avoided his father's footsteps and majored in philosophy and psychology at Haverford College, from which he was graduated Phi Beta Kappa in 1936. Alex transferred to Columbia University for his graduate work, with a research fellowship at the New York State Psychiatric Institute and Hospital. He earned his doctorate in psychology from Columbia in 1939, with Carney Landis as his mentor and with Sigma Xi honors.

One of Alex's duties at the Psychiatric Institute was to administer Rorschach tests for subsequent interpretation by Zygmunt Pietrowski, who became famous for his phenomenally accurate blind diagnoses based on the recorded protocols. The specificity of some of Pietrowski's diagnoses, such as "conversion hysteria with erection impotency," was amazing, and Alex began to suspect that he was unintentionally giving Pietrowski more information in his protocols than could be attributed solely to the patients' verbal responses to the ink blots. This suspicion led to Alex's pioneer experimental study of the "Perception of Subliminal Visual Stimuli," which appeared in the *Journal of Psychology* in 1938.

The War Years

His new Ph.D. in hand, Alex joined Jack Jenkins as a research associate at the University of Maryland in 1939, learned to fly airplanes, and became an "aviation psychologist." Their research was sponsored by the National Research Council's Committee on Aviation Psychology, chaired by Morris Viteles of the University of Pennsylvania, and was funded by the Civil Aeronautics Administration. Their project was the experimental investigation of tension as a determinant of performance in flight training. As a graduate student, Alex had experimented with electroencephalograms (Rahm & Williams, 1938; Williams, 1939, 1940), and for the pilot training research he developed an airborne polygraph to measure the physiological tension of student pilots and its correlation with flying performance.

A preliminary report of this work was submitted in 1941, but the report was not issued until five years later (Williams, Macmillan, & Jenkins, 1946). A war had intervened, and Alex, who had joined the U.S. Navy as a psychologist in September of 1941 to do research on pilot selection and training, volunteered as a naval aviator on December 8, 1941, the morning after the Pearl Harbor attack. He was assigned as a primary flight instructor and soon as squadron commander at a civilian flying school in Ottumwa, Iowa, but was impatient and kept applying for transfers to combat duty.

Finally, in 1944, he was reassigned, not to combat but to the Naval Air Transport Service. The remarks at the end of his transition training report read: "Plane commander material. Good headwork. Keeps ahead of ship. Smooth pilot." Sweet words to be sure, and remarkably perceptive. Alex's station for the rest of the war was N.A.S. Miami, from which he ferried Douglas R4Ds, the U.S. Navy's version of the famous DC-3, over the Brazilian jungles and on to the Ascension Islands on their way to the European Theater.

The Illinois Years

After this unglamorous but hazardous duty, Alex returned to civilian life as a research assistant professor at the University of Illinois, and on January 1, 1946, his Aviation Psychology Laboratory came into existence. Alex had been hired by Herbert Woodrow, the imperious head of the psychology department and forty-ninth president of the American Psychological Association, who had been involved in pilot selection during World War I. Woodrow recognized the unprecedented opportunity to develop an aviation psychology program in conjunction with the new Institute of Aviation at Illinois, and he saw in Alex a man who had the education, experience, motivation, and creativity to do just what Woodrow had in mind.

Unfortunately the psychology department had no money to invest in experimental equipment, and there was no laboratory space at the airport. Woodrow suggested that Alex's connections in the Navy might be tapped for support and that, in the meantime, it might be a good idea for Alex to pay a visit to Dean Carmichael of the graduate college. Evidently the aging dean was also a good judge of young psychologists; after listening to Alex's plans, Carmichael promised him $10,000 annually as seed money-enough for a secretary, two graduate research assistants, an instrument maker, office and shop supplies, and travel expenses for Alex to pursue his U.S. Navy and National Research Council connections.

By the fall semester of 1946 the program was on track. Support came quickly from the Special Devices Center of the Office of Naval Research, including a small building at the airport for an office and lab, several Link trainers, and later two large Quonset buildings, one in-

eluding a well-equipped machine shop. Other contracts followed with the Wright Air Development Center, the Air Force Human Resources Research Center (later the Personnel and Training Research Center), and the Civil Aeronautics Administration via the National Research Council.

With the contracts came support for a stream of graduate students, most of them pilots, who were soon swept up in Alex's zeal to solve scientifically the operational and training problems of pilots and air traffic controllers. Albert Heyer and I, the first two, were followed by David Saunders, Thomas Payne, Beatrice Johnson (Matheny), and Douglass Nicklas. Then came the flood: John Bell, Paul Dittman, Marilyn Link, Malcolm Ritchie, Dora Dougherty (Strother), Ralph Flexman, James Smith, Scott Hasler, Edward Brown, William Brown, Elizabeth Seely, Archer Michael, Fred Muckier, Michael Seven, Sally Speigel (Seven), Lowell Wilkerson, Marvin Adelson, Jack Nygaard, James Skeen, Frank Serio, Richard Obermayer, and others who came and went.

To these disciples, Alex was "The Father," the purveyor of "The Truth" in the systematic study of the human factors in aviation equipment design and pilot training. The truth was dispensed mainly around his large oak table in the conference room in a marathon feast of ideas, methods, and black coffee. Logical analysis (Williams, 1947a, 1971, 1980; Williams & Heyer, 1947a) was followed by multifactor experiments in real airplanes and flight, navigation, and air traffic control simulators. Unprecedented methods of manipulating experimental conditions were devised, and the measurement of pilot performance was objectified and standardized, all before the golden age of computers.

The initial focus was on the human engineering of flight instrument displays, starting with Alex's dial-reading studies with Walter Grether of the AeroMedical Lab at Wright Field in Dayton, Ohio (Grether & Williams, 1947; Williams & Grether, 1947; Grether, 1949; Grether & Williams, 1949). These were followed in rapid succession by the rotating-room studies of vestibular and visual orientation (Williams & Heyer, 1947a, 1949b; Heyer, 1947; Williams, 1947b; Johnson & Williams, 1949/ 1972), and-to be discussed later-the flight by periscope experiments, the area navigation display inventions and evaluations, and the air traffic control simulation studies.

Meanwhile, in 1947, reports of the motor skill studies at the University of Iowa gave Alex the idea that the transfer paradigms of the basic learning theorists were equally applicable to the quantitative assessment of the training value of Ed Link's new School Link contact flight trainer (Williams & Flexman, 1949a, 1949b; Flexman, Matheny, & Brown, 1950). Then came the prototype 1-CA-2 Link, the first true simulator of a specific airplane, the North American SNJIT-6 Texan. A salvaged forward cockpit of a wrecked Texan, with its controls and displays made operative, was mounted on the bellows of a 1-CA-1 Link (the last of the "blue boxes") and delivered to the lab for evaluation.

The transfer of training experiments that followed (Williams & Flexman, 1949c; Williams, 1951; Flexman, Roscoe, & Williams, 1952; Flexman, Roscoe, Williams, & Williges, 1972) provided ammunition for a classic promotional brochure by Paul Dittman, who had been sent to illinois by Link to keep an eye on the project while studying for his master's degree. Dittman's brochure, titled "The Proof of the Pudding," led to the first postwar procurement of P-1 Link trainers by the U.S. Air Force and the renewed profitability of Link Aviation, which had been reduced to manufacturing canoes when the market for blue boxes vanished after the war.

The original 1-CA-2 Link stayed at illinois and became the lab's second workhorse, joining the 1-CA-1 Link, which was used in the National Research Council program to develop the optimum display of bearing and range information to be provided by the CAA's new VOR-DME radio navigation facilities. Alex had advanced the notion of the integrated presentation of flight information (Williams, 1947a), which led to his conception of map displays on which the airplane's position and heading are plotted automatically. Early paper and pencil tests, in which pilots made rapid navigation decisions in response to drawings of various instrument displays, supported Alex's thesis (Williams & Roscoe, 1948, 1949a, 1950; Williams, 1949a).

With the evident superiority of map displays, Alex had John Bell build the first CRT map display (that's right, CRT!) and install it in the cockpit of the 1-CA-1 Link for experimental evaluation (Roscoe, Smith, Johnson, Dittman, & Williams, 1950). On the strength of the striking improvements in the pilots' performance of terminal area instrument flight procedures, the CAA embarked on its pioneering program to develop airborne map displays and test them in flight at the Technical Development and Evaluation Center in Indianapolis. Meanwhile at the lab, Alex and Tom Payne pursued the investigation of the principles of control-display motion compatibility in map displays (Payne, 1950a, 195Gb, 1952a, 1952b; Payne & Williams, 1954).

The flight by periscope experiments (Roscoe, 1947, 1948, 1950, 1951, 1984; Williams & Roscoe, 1949b; Roscoe, Hasler, & Dougherty, 19521 1966), which were started in early 1947 and continued until 1952, were conceived in response to the U.S. Navy's interest in the potential of television for the flight control of airborne vehicles, whether flown from the cockpit or remotely. It was obviously impractical to install a laboratory full of optical and electrical hardware in a flight test airplane at that time, so Alex suggested that a TV display could be simulated by means of a periscope that projected the image of the outside world on a screen mounted above the instrument panel in the cockpit of the lab's Cessna T-50. I was his first graduate student who was also a pilot and so got that prize assignment.

Alex's flair for inventive gadgetry came in handy again when the CAA asked the lab to develop the first air traffic control simulator (Johnson, Williams, & Roscoe, 1951). Alex had Al Bowman, the lab's machinist, build four long, thin tables in the lab, with four large, identical maps equally spaced on each table. Surplus Link trainer "crabs" (flight path trackers) were in long supply in those days, and Alex had Bowman mount an ingenious electromechanical device above each map to sense the bearing and range of a crab from the center of its map, which represented the ground location of the air traffic control radar. The same was done for the crabs of the 1-CA-1 and 1-CA-2 Link trainers, and the positions of all 18 crabs were "telemetered," as we used to say, to a large radar scope in the "air traffic control tower."

Pilots "flew" the crabs with heading, speed, and altitude controls in compliance with the clearances issued by the "controllers" to study the feasibility and effectiveness of various experimental terminal area ATC procedures (Johnson, 1953). Bill Jackson, the director of the Technical Development and Evaluation Center, saw the potential of the simulator as a research and training tool. He had it moved to Indianapolis and integrated with the real-world ATC system so that controllers in the Indianapolis tower could get "high-density" practice by controlling the simulated airplanes (crabs) intermixed with the real airplanes in the terminal area. That Illinois ATC simulator was the predecessor of the FAA's elaborate facility now at the Technical Center in Atlantic City.

The first major transfer of training experiment in the 1-CA-2 Link had demonstrated its effectiveness in teaching all primary flight tasks except takeoffs and landings. Ralph Flexman had also shown, with many doubters, that landings could be taught with significant positive transfer using a picture of an airport runway drawn on a blackboard. Flexman tilted the blackboard about its horizontal axis as a student in a School Link "rounded out" for a "landing." Surely, Alex reasoned, if such a crude display had any transfer value, a closed-loop visual system could be highly effective in teaching beginners to land, thereby reducing the hazards of early dual landing trials.

Point light sources had been used in celestial navigation trainers, and

Alex came up with the idea of using a small, bright source to rear-project a properly dynamic geometric image of a runway on a screen set up :in front of the 1-CA-2 Link (Williams, 1949a; Bell, 1951). A sheet of aluminum, with a slit cut out to represent a landing runway, was mounted over a Link trainer crab with an elevator mechanism driven by the simulator's "altitude." The crab traveled over a table behind the screen in direct response to the simulator's "heading" and "speed." The error reduction of 85% and the saving of 61% of the flight trials relative to· a control group (Payne, et al., 1954) would be hard to match with present-day computer animation.

The projects just described do not constitute the entire program, but they are sufficient to illustrate Alex's interests and genius. His penchants for logical analysis and rigorous experimentation were supported by his love of gadgetry and his remarkable ability to devise simple ways of simulating complex devices and systems. He was truly an *engineering* psychologist, a facility recognized early by engineers as well as psychologists. He was called on repeatedly to serve on blue ribbon committees on subjects ranging from air navigation and traffic control to the operation and maintenance of all-weather :interceptor systems (e.g., Williams, 1951; Fitts et al., 1951; Licklider et al., 1953; Fitts, Flood, Garman, & Williams, 1957).

Unfortunately, Alex published no books and only 11 journal articles, all prior to 1951 and the first four of which were in the clinical psychology field. Most of what he left us appeared only :in technical reports or conference proceedings, but these were read by virtually everyone :in the field at that time and had an immediate impact. Between 1938 and 1958, Alex contributed seminal papers :in the following areas:

Perception of subliminal visual stimuli (Williams, 1938)
Use of polygraphs in airborn pilot performance research (Williams, Macmillan, & Jenkins, 1946)
Speed and accuracy of dial-reading as a function of display design (Grether & Williams, 1947)
Analysis of information requirements for :instrument flight (Williams, 1947a/980)
Analysis of manipulation :in the manual control of airplanes (Williams, 1947c/980)
Vestibular and visual factors affecting spatial orientation :in flight (Williams, 1947b; Johnson & Williams, 1949)
Desirable display characteristics for aircraft instruments (Williams, 1949b)
Integrated, map-type pictorial displays for area air navigation (Williams & Roscoe, 1949a; Roscoe, Smith, Johnson, Dittman, & Williams, 1950)
Transfer of flight training :in simulators to performance :in airplanes (Williams & Flexman, 1949c)
Simulation as a tool in the design of air-traffic-control systems (Johnson, Williams, & Roscoe, 1951)
Pilot decision making and the allocation of human and machine functions (Williams & Hopkins, 1958)

Alex and Raymond B. Cattell, although at opposite extremes of the scientific rigor continuum, were the two main breadwinners in the psychology department at Illinois during the late 1940s and early 1950s. Alex and Raymond B. Cattell, although at opposite extremes of the Their contracts and grants supported more graduate students than the rest of the department combined. Herbert Woodrow appreciated the importance of Alex's contribution to the department and encouraged him in every way he could. Woodrow served on the doctoral committees of Alex's early graduate students and otherwise left Alex alone to obtain contracts and nm the Aviation Psychology Laboratory as he saw fit.

Alex was a charming man, and his relationships with other faculty :in the department were uniformly friendly and stimulating. Arthur Irion, at that time an assistant professor at lllinois, remembers Alex for "his warmth and k:indness, his marvelous-if somewhat wry-sense of humor, his loyalty to friends and his (sometimes somewhat strained) tolerance for those who opposed him." Scott Hasler, a research assistant and pilot who was not an advanced degree candidate but was later to become vice president for engineering of the Bunker-Ramo Corporation, was "accepted by him as a person" and was "not only permitted but encouraged to contribute" to the lab's team research efforts.

However, concurrent with Woodrow's retirement :in 1951, the complexion of the department was changing rapidly. Many veterans who had entered college after the war were flooding the clinical program, placing heavy demands on the department's limited resources. New faculty, :including the head, were advancing their own agenda. The aviation lab at the university airport, not on the main campus, was routinely bypassed :in the resource allocation process. The prevailing philosophy :in the department was that indirect funds generated by contracts should be used to provide equipment, travel to meetings, and graduate assistants for faculty who didn't have contracts; those who did didn't need any more money.

Alex agreed with this "seed money" concept, which had served him and the department well :in 1946, but pointed out that it could be disastrous if carried to the limit. Laboratory heads would be forced to charge their cost of doing business items, for which the indirect funds were largely intended, directly to contracts. A notable example, over which there was heated contention, was the cost of "proficiency time" for the pilots in the lab to maintain legal currency during an occasional long hiatus between flight experiments for some. Government auditors were not amused when proficiency time was charged to a contract, and Alex bore the brunt of the inquisitions.

Alex also pointed out that soft-money research programs were subject to peaks and valleys and that a reserve of indirect funds was needed to fill in the valleys and maintain a stable operation. The position of the campus administration was that such contingencies would be dealt with on an individual basis, not by allowing the lab to build up a reserve of indirect funds. The lab's return of such funds would remain at $10,000 a year, even though Alex was generating several times that amount by then. Soon thereafter, his concerns were vindicated.

The paperwork for a new, multiyear contract with the Air Force, which was to have supported a large fraction of the lab's staff starting in the fall of 1953, was lost somewhere in a series of in-baskets. The mixup was eventually straightened out by Arthur Melton, director of the Air Force Personnel and Training Research Center, but by that time the contract could not be accepted; several who were to have worked on the program had not been given interim appointments by the university and had taken jobs elsewhere, some without completing their Ph.Ds.

During the preceding summer, Alex had been asked to help on a human factors study of the operation and maintenance of all-weather interceptor systems led by J. C. R. Licklider of MIT. In the course of that study, Lick and Alex and the others had visited Hughes Aircraft Company in California. I had left Illinois and joined Hughes the year before and had been doing flight and simulator research and display and control design work on the Hughes radar-directed air-to-air attack systems and on map displays. My management at Hughes were impressed with Lick and Alex and their knowledgeable, constructive, and highly supportive Project Jay Ray report (Licklider et al., 1953) and quite receptive to my suggestion that they try to hire Alex.

By that time Alex was on the verge of deciding to leave Illinois, and I happened to be visiting the lab when he knew for sure that leaving was his only choice. He had been called to campus and told that the lab would no longer receive any indirect funds; the department needed the $10,000. I had never seen Alex so mad or so defeated. However, he was not one to abandon his graduate students and staff without warning, so

he honored his 1954 contract with the university and did not join us at Hughes until the summer of 1955. My old boss was now my new boss as head of the cockpit research section.

The Hughes Aircraft Years

Alex quickly won the respect, confidence, and friendship of the Hughes engineers. The revolutionary design concepts I had been advancing against adamant resistance, such as map displays and moving-airplane attack displays for all-weather interceptors (Roscoe, 1955), were taken more seriously when Alex calmly explained why they were goe5d ideas and needed. Hughes was in the midst of developing the MA-l aircraft and weapon control system for the Convair F-106 interceptor, and Alex persuaded management to assign a large group of engineers to develop from scratch a completely integrated cockpit subsystem based directly on the research done by Alex and his students at Illinois (Roscoe, 1957).

The development of the new cockpit displays and controls, including flight instruments as well as radar and navigation displays, was done in parallel with two other engineering innovations. Previously, Air Force approval of new airplane designs had ben based on inspection of static mockups that included lighted but inoperative instruments and controls. With Alex's persuasion, the Hughes management and the Air Force project officer authorized development of dynamically func- tional laboratory and airborne simulations of the proposed *F-l06IMA-* 1 cockpit subsystem. The laboratory simulator was driven by a huge REAC analog computer. The airborne version, driven by operational sensors, was installed in the rear cabin of a Convair T-29 transport that could be flown remotely from the experimental F-106 cockpit, the first airborne flight simulator.

The ease of learning to use the Hughes displays and controls and their superiority over conventional flight and navigation instruments were evident to the Hughes and Convair engineers and the Air Force project officer. However, neither Alex nor the Hughes management was prepared for the vicious jurisdictional battle precipitated by the invasion of foreign turfs by Hughes and its aviation psychologists. The turfs in question included those of the company and Air Force test pilots, who had always controlled the selection and arrangement of the myriad clock-faced cockpit dials, which in turn were developed and procured by the Air Force laboratories at Wright Field and manufactured by a small number of companies with a joint monopoly on the flight instrument business.

The eventual compromise satisfied no one completely. However, although the F-106 cockpit fell short of what it might have been, it did mark a break from jurisdictional tradition, with Hughes producing the first operational map-type navigation display as a part of the aircraft and weapon control system. The moving-airplane flight attitude and attack displays were replaced by moving horizons; the moving pointers of the vertical-scale airspeed, altitude, and vertical speed displays were replaced by moving scales with lubber lines; and the map display, though saved, was reduced to two-thirds its original size at a cost of millions.

The F-106 experience was a bitter dose for Alex and the rest of us psychologists. But Alex had learned an important lesson that served him well on the next major project the North American F-108 long-range interceptor. This time each of the Air Force officers who comprised the F-108 Mockup Board was invited to visit Hughes individually and fly the F-108 simulator in its various operating modes, all of which were fully explained. Each officer's performance was recorded and scored, both with the proposed display system and with conventional displays, and the records were given to the individual to take back to the Pentagon for comparison with the scores of the other board members.

Without exception, it was evident to the officers that they had performed far better from the outset with the proposed displays than with those with which they were already proficient. At the next mockup inspection, in a unanimous vote, the new display and control system was adopted without exception. Ironically, Alex's victory was followed one week later by the announcement of the cancellation of the F-108 aircraft program. How the Hughes displays and controls for the F-108 might have influenced the future of aircraft cockpit instrumentation design would never be known.

Mysteriously further development of the Hughes ASG-18 weapon system was not canceled (Roscoe, Partridge, & Heineman, 1959), and work on the system continued, with equipment being transferred in and out through "the green door" in Building 5 at Culver City. In 1962 President Johnson cleared up the mystery for all of us when he announced the existence of the hypersonic reconnaissance Lockheed SR-71 and its long-range interceptor counterpart, the YF-12, which secretly contained the ASG-18 system. Alex and his staff had been working on Kelly Johnson's "skunk works" project for five years without knowing about the supersecret airplane.

It was during the development of the ASG-18 radar that Alex showed Hughes his analytical and inventive genius. By that time Alex was the manager of the Display Department of the Signal Processing and Display Laboratory, supervising engineers as well as psychologists. During the summers of the late 1950s, he brought his friend and fellow genius J. C. R. Licklider out from MIT to work with us at Hughes. Prior to that time, all air-to-air radars were of the brute-force pulse type. One powerful pulse of radio-frequency energy was transmitted and its echo received before the next was emitted. If the returning echo were sufficiently strong, a "blip" could be detected above the noise and ground clutter at the target's range and azimuth on the radar scope.

Alex and Lick reasoned that if a sinusoidal wave of radio energy were transmitted, echoes from moving airborne targets could be more clearly discriminated from the ground clutter by their differential Doppler shifts, thereby greatly increasing detection range without increasing power. Continuous wave (CW) radars existed, but they had never been tried for air-to-air applications because the information the Doppler effect provides is the relative closing or opening speed of a target (as with highway patrol radar guns); it provides no information concerning the range of the target, needed for attack maneuvering computations.

Alex and Lick reasoned further that if the coordinates of an airborne radar display were changed from range versus azimuth to range rate versus azimuth, all of the returns from ground clutter would appear as a thin, bright arc indicating the radial speed of ground objects relative to the flight path of the airplane. Only targets moving directly orthogonal to the radar's momentary line of sight would be obscured by the clutter arc, and all others would appear in the clear portions of the display. If targets were detected at far greater ranges than with conventional pulse radars, surely there would be sufficient time to resolve the range ambiguity by other means.

Alex and Lick presented their ideas to Harold Hance, a physicist in the radar analysis section, and among the three of them the pulse-Doppler air-to-air radar was invented. By emitting short bursts, or pulses, of CW energy at a constant pulse repetition frequency (PRF), the range rate versus azimuth display would allow target detection at unprecedented ranges, and by designating an individual target on the display and then varying the PRF and analyzing the timing of the CW returns, the target's range could be determined. The ASG-18 was the first operational pulse-Doppler radar, now the standard type in interceptor aircraft.

In 1957 Alex and Charles Hopkins were working on a small study contract with the AeroMedical Laboratory at Wright Field (Williams & Hopkins, 1958). When the Russians orbited the first unmanned sputnik, Alex and Chuck immediately prepared a proposal titled "Displays and

Controls for Manned Space Flight" and presented it to the AeroMedical Lab. The resulting contract (Hopkins, Bauerschmidt, & Anderson, 1960) was the first in the Air Force's Man in Space Soonest program. A subsequent display and control system design study for NASA (Hopkins, Bauerschmidt, & Roscoe, 1961), together with the flawless performance of the Surveyor unmanned lunar landings, placed Hughes in the catbird seat in the spacecraft display and control business.

During the preproposal phase of the Apollo program, Alex and Gordon Murphy of the Hughes marketing staff discussed teaming arrangements with all the major competitors for the prime contract. They concluded that for various reasons none was in a position *to* handle a program of such magnitude. However, North American Aviation, which was not yet in the space business, was overflowing with engineering talent and production capacity left over from the canceled F-108 and B-70 programs. Alex and Gordon convinced the North American management that none of the major competitors could do the job and that a North American-Hughes Aircraft team could win the prime contract.

A few days later, Pat Hyland, the general manager of Hughes, who was unaware of the negotiations with North American, was surprised to find himself on the same flight back from Washington with J. S. McDonnell of the McDonnell Aircraft Company. "Old Mac," as he called himself, was forming an "unbeatable" team with three of his bitterest competitors, Chance-Vought, Lockheed, and Douglas, and invited Hughes-also no friend of the McDonnell Company-to join the team, which Hyland agreed to do (Roscoe, Hopkins, & Bauerschmidt, 1961).

What the senior McDonnell knew, and Hyland did not know, was that NASA couldn't wait for Apollo while the Russians were racing ahead and that McDonnell was about to receive a contract for the interim Gemini program, as Gordon Murphy had predicted. With the McDonnell team out of the picture, North American won Apollo and, when asked again, said they were sure they could do the job without Hughes. Alex was deeply disappointed at being left behind in the manned space race.

The Final Year

By then Alex was managing a sizable engineering operation as well as the simulation, experimentation, and functional design projects of the psychologists and human factors engineers. Alex had risen in the

Hughes organization to the point where his job was no longer fun, and the constant in-fighting and turf battles above, below, and around him battered his gentle nature. He had developed hypertension, which worried us all, including the Hughes medical staff. One morning in 1962, I answered my telephone, and a teenage girl's voice whispered, "Stan, Daddy won't be coming to work this morning, and he won't be coming any more. He had a heart attack last night coming up the stairs from the basement. We found him there this morning."

References

Bell, J. M. (1951). *A landing display for use with a contact flight simulator* (Technical Report 71-16-7, Contract N6ori-71, Task Order XVI). Port Washlngton: Office of Naval Research, Special Devices Center.

Fitts, P.M. (Ed.), Chapanis, A., Frick, F. C., Garner, W. R., Gebhard, J. W., Grether, W. F., Henneman, R. E., Newman, W. B., & Williams, A. C., Jr. (1951). *Human engineering for an effective air-navigation and traffic-control system.* Washlngton, D.C.: National Research Council, Committee on Aviation Psychology.

Fitts, P.M., Flood, M. M., Garman, R. A., & Williams, A. C., Jr. (1957). *The USAF human factor engineering mission as related to the qualitative superiority of future man-machine weapon systems.* Washlngton, D.C.: U.S. Air Force Scientific Advisory Board, Working Group on Human Factor Engineering Social Science Panel.

Flexman, R. E., Matheny, G. W., & Brown, E. L. (1950). Evaluation of the School Link and special methods of instruction in a ten-hour private pilot flight-training program. *University of Illinois Bulletin,* 47(80; Aeronautics Bulletin 8).

Flexman, R. E., Roscoe, S. N., & Williams, A. C., Jr. (1952). *Evaluation of the 1-CA-2 Link as a contact and an instrument flight trainer* (Unnumbered [8]. Contract N6ori-71, Task Order XVI). Savoy: University of illinois Department of Psychology, Aviation Psychology Laboratory.

Flexman, R. E., Roscoe, S. N., Williams, A. C., Jr., & Williges, B. E. (1972). Studies in pilot training: The anatomy of transfer. *Aviation Research Monographs,* 2(1).

Grether, W. F. (1949). Instrument reading: The design of long-scale indicators for speed and accuracy of quantitative readings. *Journal of Applied Psychology,* 33, 363-372.

Grether, W. F., & Williams, A. C., Jr. (1947). *Speed and accuracy of dial reading as a function of dial diameter and spacing of scale divisions* (Memorandum Report TSEAA 694-1E; ATI 27507). Wright-Patterson Air Force Base: Air Materiel Command.

Grether, W. F., & Williams, A. C., Jr. (1949). Psychological factors in instrument reading: II. The accuracy of pointer position interpolation as a function of the distance between scale marks and illumination. *Journal of Applied Psychology, 331* 594-604.

Heyer, A. W., Jr. (1947). *Visual illusory effects accompanying vestibular stimulation:*

Relationship to current theory. Master's thesis in engineering psychology, University of illinois.

Hopkins, C. O., Bauerschmidt, D. K., & Anderson, M.J. (1960). *Display and control requirements for manned space flight* (WADD Technical Report 60-197). Wright Patterson Air Force Base: Wright Air Development Division.

Hopkins, C. O., Bauerschmidt, D. K., & Roscoe, S. N. (1961). *APOLLO display and control subsystem* (Technical Memorandum TM-680). Culver City: Hughes Aircraft Company, Aerospace Group.

Johnson, B. E. (1953). *Vectoring aircraft by radar: The effect of load and speed differences on controllers' performance in a simulated air traffic situation.* Ph.D. dissertation in engineering psychology, University of illinois.

Johnson, B. E., & Williams, A. C., Jr. (1949). *Obedience to rotation-indicating visual displays as a function of confidence in the displays* (Interim Rep_ort 71-16-2, Contract N6ori-71, Task Order XVI). Port Washington: Office of Naval Research, Special Devices Center.

Johnson, B. E., & Williams, A. C., Jr. (1972). Obedience to rotation-indicating visual displays *as* a function of confidence in the displays. In S. N. Roscoe & B. H. Williges (Eds.), Three lessons in aviation research. *Aviation Research Monographs,* 1 (3), 11-25.

Johnson, B. E., Williams, A. C., Jr., & Roscoe, S. N. (1951). *A simulator for studying human factors in air traffic control systems* (Report 11). Washington, D.C.: National Research Council, Committee on Aviation Psychology.

Licklider, J- C. R., Clementson, G. C., Doughty, J- M., Huggins, W. H., Seeger, C. M., Smith, C. C., Williams, A. C., Jr., & Wray, J. (1953). *Human factors in the operation and maintenance of all-weather interceptor systems: Conclusions and recommendations of Project Jay Ray, a study group on human factors in all-weather interception* (HFORL Memorandum 41). Bolling Air Force Base: Human Factors Operations Research Laboratories.

Payne, T. A. (1950a). *A study of the moving part and orientation of symbols on pictorial aircraft instrument displays for navigation.* Master's thesis in engineering psychology, University of illinois.

Payne, T.A. (1950b). *A study of the moving part and orientation of symbols on pictorial aircraft instrument displays for navigation* (Technical Report 71-16-6, Contract N6ori-71, Task Order XVI). Port Washington: Office of Naval Research, Special Devices Center.

Payne, T. A. (1952a). *A study of the moving part, heading presentation, and map detail on pictorial air navigation displays* (Human Engineering Report SPECDEVCEN 71-16-10, Contract N6ori-71, Task Order XVI). Port Washington: Office of Naval Research, Special Devices Center.

Payne, T. A. (1952b). *A study of the moving part, heading presentation, and map detail on pictorial air navigation displays.* Ph.D. dissertation in engineering psychology, University of illinois.

Payne, T. A., & Williams, A. C., Jr. (1954). Recommended features for pictorial computer displays for air navigation. Appendix to R. E. McCormick & F. S. McKnight. *The type V pictorial computer with automatic chart selection: Part II. Technical and operational evaluation* (Technical Development Report 243, pp. 12-16.) Indianapolis: Civil Aeronautics Administration, Technical Development and Evaluation Center.

Payne, T. A., Dougherty, D. J., Hasler, S. G., Skeen, J-R., Brown, E. L., & Williams, A. C., Jr. (1954). *Improving landing performance using a contact landing trainer* (Technical Report SPECDEVCEN 71-16-11, Contract N6ori-71, Task Order XVI). Port Washington: Office of Naval Research, Special Devices Center.

Rahm, W. E., Jr., & Williams, A. C., Jr. (1938). Aspects of the electroencephalogram in epilepsy and feeblemindedness. *Psychiatric Quarterly,* 12, 230-235.

Roscoe, S. N. (1947). *The effects of eliminating binocular and peripheral monocular visual cues upon airplane pilot performance in landing.* Master's thesis in engineering psychology, University of illinois.

Roscoe, S.N. (1948). The effects of eliminating binocular and peripheral monocular visual cues upon airplane pilot performance in landing. *Journal of Applied Psychology,* 32, 649-662.

Roscoe, S. N. (1950). *Aircraft pilot performance as a function of the extent and magnification of the visible horizon.* Ph.D. dissertation in engineering psychology, University of illinois.

Roscoe, S. N. (1951). Flight by periscope: I. Performing an instrument flight pattern; the influence of screen size and image magnification. *University of Illinois Bulletin, 48(55;* Aeronautics Bulletin 9).

Roscoe, S. N. (1955). A long range cockpit research and development program: Part II. In *Final report, 1955 USAF Instrument Symposium, Section IX. Classified supplement.* Moody Air Force Base: United States Air Force.

Roscoe, S. N. (1957). The development of integrated instrument display panels at Hughes Aircraft Company. In M. L. Ritchie & C:. A. Baker (Eds.), *Psychological aspects of cockpit design-A symposium report* (Technical Report WADC 57-117, pp. 28--40). Wright-Patterson Air Force Base: Wright Air Development Center.

Roscoe, S. N. (1984). Judgments of size and distance with imaging displays. *Human Factors, 26,* 617-630.

Roscoe, S. N., Hasler, S. G., & Dougherty, D.J. (1952). *Flight by periscope: II. Making takeoffs and landings; the influence of image magnification, practice and various conditions of flight* (Human Engineering Report SDC 71-16-9, Contract N6ori-71, Task Order XVI). Port Washington: Office of Naval Research, Special Devices Center.

Roscoe, S. N., Hasler, S. G., & Dougherty, D.J- (1966). Flight by periscope: Making takeoffs and landings; the influence of image magnification, practice, and various conditions of flight. *Human Factors, 8,* 13--40.

Roscoe, S. N. Hopkins, C. O., & Bauerschmidt, D. K. (1961). *APOLLO spacecraft displays and controls* (Technical Memorandum TM-691). Culver City: Hughes Aircraft Company, Aerospace Group.

Roscoe, S. N., Partridge, A. B., & Heineman, R. E. *(1959). AN/ASG-18 fire control subsystem: Human factors data* (Report ASG-18-74-S). Culver City: Hughes Aircraft Company, System Development Laboratories.

Roscoe, S. N., Smith, J. F., Johnson, B. E., Dittman, P. E., & Williams, A. C., Jr. (1950). *Comparative evaluation of pictorial and symbolic VOR navigation displays in the 1-CA-1 Link trainer* (Report 92). Washington, D.C.: Civil Aeronautics Administration, Division of Research.

Williams, A. C., Jr. (1938). Perception of subliminal visual stimuli. *Journal of Psychology,* 6,187-189.

Williams, A. C., Jr. (1939). Some psychological correlates of the electro-encephalogram. *Archives of Psychology, New York, 34* (Whole No. 240).

Williams, A. C., Jr. (1940). Facilitation of the alpha rhythm of the electro-encephalogram. *Journal of Experimental Psychology, 26,* 413-422.

Williams, A. C., Jr. (1947a). *Preliminary analysis of information required by pilots for instrument flight* (Interim Report 71-16-1, Contract N6ori-71, Task Order XVI). Port Washington: Office of Naval Research, Special Devices Center.

Williams, A. C., Jr. (1947b). *Evaluation and development of aircraft instrument designs: I. Altitude control. II. Theory of vestibular stimulation* (Progress Report 4, Contract N6ori-71, Task Order XVI). Port Washington: Office of Naval Research, Special Devices Center.

Williams, A. C., Jr. (1947c). *Evaluation and development of aircraft instrument designs: Analysis of manipulation* (Progress Report 6, Contract N6ori-71, Task Order XVI). Port Washington: Office of Naval Research, Special Devices Center.

Williams, A. C., Jr. (1949a). *Part I. Pilot performance using VOR in the 1-CA-1 Link trainer. Part II. Design and construction of equipment for use in making instrument approaches and landings in the SNJ Link trainer* (Progress Report 2). Washington, D.C.: National Research Council, Committee on Aviation Psychology.

Williams, A. C., Jr. (1949b). *Suggestions concerning desirable display characteristics for aircraft instruments* (Technical Report 71-16-4, Contract N6ori-71, Task Order XVI). Port Washington: Office of Naval Research, Special Devices Center.

Williams, A. C.,Jr. (1951). Research on synthetic trainers. In *Conference for planning psychological research related to optimum utilization of B-50 electronic flight simulators.* Lackland Air Force Base: Human Resources Research Laboratoy.

Williams, A. C., Jr. (1971). Discrimination and manipulation in goal-directed instrument flight. *Aviation Research Monographs,* 1(1), 1-54.

Williams, A. C., Jr. (1980). Discrimination and manipulation in flight. In S. N. Roscoe, *Aviation Psychology.* Ames: Iowa State University Press.

Williams, A. C., Jr., & Flexman, R. E. (1949a). Evaluation of the School Link as an aid in primary flight instruction. *University of Illinois Bulletin* 46(71; Aeronautics Bulletin 5).

Williams, A. C., Jr., & Flexman, R. E. (1949b). The efficiency of a synthetic flight training device as a function of its design characteristics. *American Psychologist, 4,* 301.

Williams A. C., Jr., & Flexman, R. E. (1949c). *An evaluation of the Link SNJ operational trainer as an aid in contact flight training* (Technical Report 71-16-5, Contract N6ori-71, Task Order XVI). Port Washington: Office of Naval Research, Special Devices Center.

Williams, A. C., Jr., & Grether, W. F. (1947). Legibility of instrument dials as a function of dial diameter and the spacing of scale *divisions. American Psychologist* 2, 348.

Williams, A. C., Jr., & Heyer, A. W., Jr. (1947a). *Evaluation and development of aircraft instrument designs: I. Analysis of information required for instrument flight. II. Rationale and preliminary results of investigation concerning vestibular junction* (Progress Report 2, Contract N6ori-71, Task Order XVI). Port Washington: Office of Naval Research, Special Devices Center.

Williams, A. C., & Heyer, A. W., Jr. (1947b). *Evaluation and development of aircraft instrument designs: Results of preliminary investigation concerning vestibular function* (Progress Report 3, Contract N6ori-71, Task Order XVI). Port Washington: Office of Naval Research, Special Devices Center.

Williams A. C., & Hopkins, C. O. (1958). *Aspects of pilot decision making* (WADC Technical Report 58-522). Wright-Patterson Air Force Base: Wright Air Development Center.

Williams, A. C., Jr., Macmillan, J. W., & Jenkins, J. G. (1946). *Preliminary experimental investigations of "tension" as a determinant of performance in flight training* (Report 54, Publication Bulletin L50325). Washington, D.C.: Civil Aeronautics Administration, Division of Research.

Williams, A. C., Jr., & Roscoe, S. N. (1947). *Evaluation and development of aircraft instrument designs: I. Study of pilot performance while making instrument approaches and landings with the use of a projection periscope. II. Initial study of altitude control in the Link trainer and in simulated instrument flight in the SNJ-4* (Progress Report 5, Contract N6ori-71, Task Order XVI). Port Washington: Office of Naval Research, Special Devices Center.

Williams, A. C., Jr., & Roscoe, S. N. (1948). *Progress report on the evaluation of ODR instrument displays* (Unnumbered). Washington, D.C.: National Research Council, Committee on Aviation Psychology.

Williams, A. C., Jr., & Roscoe, S. N. (1949a). *Evaluation of aircraft instrument displays for use with the omni-directional radio range* (Report 84). Washington, D.C.: Civil Aeronautics Administration, Division of Research.

Williams, A. C., & Roscoe, S. N. (1949b). *Pilot performance in instrument flight as a function of the extent and distribution of visible horizon* (Interim Report 71-16-3, Contract N6ori-71, Task Order XVI). Port Washington: Office of Naval Research, Special Devices Center.

Williams, A. C., Jr., & Roscoe, S. N. (1950). Evaluation of aircraft instrument displays for use with the omni-directional radio range. *Journal of Applied Psychology,* 34,123-130.

Papers Authored, Coauthored, Mentored, or Contributed to by A. C. Williams, Jr.

Except where noted, A. C. Williams, Jr., is the sole author of the publications listed.

1938

Rahm, W. E., Jr., & Williams, A. C., Jr. (1938). Aspects of the electro-encephalogram in epilepsy and feeblemindedness. *Psychiatric Quarterly,* 12, 230-235.

---. Perception of subliminal visual stimuli. *Journal of Psychology, 6,* 187-1.99.

1939

———. Some psychological correlates of the electroencephalogram. *Archives of Psychology, New York, 34* (Whole No. 240).

1940

--. Facilitation of the alpha rhythm of the electroencephalogram. *Journal of Experimental Psychology, 26,* 413-422.

1946

Williams, A.C., Macmillan, J.W., & Jenkins, J.G. *Preliminary experimental investigations of "tension" as a determinant of performance in flight training* (Report 54, Publication Bulletin L503 25). Washington, D.C.: Civil Aeronautics Administration, Division of Research.

"

1947

Grether, W. F., & Williams, A. C., Jr. *Speed and accuracy of dial reading as a function of dial diameter and spacing of scale divisions* (Memorandum Report TSEAA 694-1E; ATI 27507). Wright-Patterson Air Force Base: Air Materiel Command.

Heyer, A. W., Jr. *Visual illusory effects accompanying vestibular stimulation: Relationship to current theory.* Master's thesis in engineering psychology, University of illinois.

Roscoe, S. N. *The effects of eliminating binocular and peripheral monocular visual cues upon airplane pilot performance in landing.* Master's thesis in engineering psychology, University of illinois.

———. *Evaluation and development of aircraft instrument designs: I. Altitude control. II. Theory of vestibular stimulation* (Progress Report 4, Contract N6ori-71, Task Order XVI). Port Washington: Office of Naval Research, Special Devices Center.

———. *Evaluation and development of aircraft instrument designs: Analysis of manipulation* (Progress Report 6, Contract N6ori-71, Task Order XVI). Port Washington: Office of Naval Research, Special Devices Center. [Published posthumously in edited form in 1971.]

———. *Preliminary analysis of information required by pilots for instrument flight* (Interim Report 71-16-1, Contract N6ori-71, Task Order XVI). Port Washington: Office of Naval Research, Special Devices Center. [Published posthumously in edited form in 1971.]

Williams, A. C., Jr., & Grether, W. F. Legibility of instrument dials as a function of dial diameter and the spacing of scale divisions. *American Psychologist,* 2, 348. [Abstract of a paper delivered for the Symposium on Visual Problems in Equipment Design at the 55th annual meeting of the American Psychological Association, September 1947.]

Williams, A. C., Jr., & Heyer, A. W., Jr. *Evaluation and development of aircraft instrument designs: I. Analysis of information required for instrument flight. II. Rationale and preliminary results of investigation concerning vestibular function* (Progress Report 2, Contract N6ori-71, Task Order XVI). Port Washington: Office of Naval Research, Special Devices Center.

Williams, A. C., Jr., & Heyer, A. W., Jr. *Evaluation and development of aircraft instrument designs: Results of preliminary investigation concerning vestibular function* (Progress Report 3, Contract N6ori-71, Task Order XVI). Port Washington: Office of Naval Research, Special Devices Center.

Williams, A. C., Jr., & Roscoe, S. N. *Evaluation and development of aircraft instrument designs: I. Study of pilot performance while making instrument approaches and landings with the use of a projection periscope. II. Initial study of altitude control in the Link trainer and in simulated instrument flight in the SNJ-4* (Progress Report 5, Contract N6ori-71, Task Order XVI). Port Washington: Office of Naval Research, Special Devices Center.

1948

Roscoe, S. N. The effects of eliminating binocular and peripheral monocular visual cues upon airplane pilot performance in landing. *Journal of Applied Psychology,* 32, 649-662. [Revised version of Roscoe, 1947.]

Williams, A. C., Jr., & Roscoe, S. N. *Progress report on the evaluation of ODR instrument displays* (Unnumbered). Washington, D.C.: National Research Council, Committee on Aviation Psychology.

1949

Grether, W. F. Instrument reading: The design of long-scale indicators for speed and accuracy of quantitative readings. *Journal of Applied Psychology,* 33, 363-372.

Grether, W. F., & Williams, A. C., Jr. Psychological factors in instrument reading: II. The accuracy of pointer position interpolation as a function of the distance between scale marks and illumination. *Journal of Applied Psychology,* 33, 594-604.

Johnson, B. E., & Williams, A. C., Jr. *Obedience to rotation-indicating visual displays as a function of confidence in the displays* (Interim Report 71-16-2, Contract N6ori-71, Task Order XVI). Port Washington: Office of Naval Research, Special Devices Center. [Same as Johnson, 1950; published in edited form in 1971.]

---. *Part I. Pilot performance using VOR in the 1-CA-1 Link trainer. Part II. Design and construction of equipment for use in making instrument approaches and landings* in *the SNJ Link trainer* (Progress Report 2). Washington, D.C.: National Research Council, Committee on Aviation Psychology.

———. *Suggestions concerning desirable display characteristics for aircraft instruments* (Technical Report 71-16-4, Contract N6ori-71, Task Order XVI). Port Washington: Office of Naval Research, Special Devices Center. [Published in edited form in 1971.]

Williams, A. C., Jr., & Flexman, R. E. The efficiency of a synthetic flight training device as a function of its design characteristics. *American Psychologist, 4,* 301. [Abstract of a paper presented for the Symposium on Psychological and Human Resources Programs of the Armed Forces and Reserve Officer Programs at the 57th annual meeting of the American Psychological Association, September 1949.]

Williams, A. C., Jr., & Flexman, R. E. *An evaluation of the Link SNJ operational trainer as an aid* in *contact flight training* (Technical Report 71-16-5, Contract N6ori-71, Task Order XVI). Port Washington: Office of Naval Research, Special Devices Center. [Included in edited and expanded form in Flexman, Roscoe, Williams, & Williges, 1972.]

Williams, A. C., Jr., & Flexman, R. E. Evaluation of the School Link as an aid in primary flight instruction. *University of Illinois Bulletin,* 46(71; Aeronautics Bulletin 5).

Williams, A. C., Jr., & Roscoe, S. N. *Evaluation of aircraft instrument displays for use with the omni-directional radio range* (Report 84). Washington, D.C.: Civil Aeronautics Administration, Division of Research.

Williams, A. C., Jr., & Roscoe, S. N. *Pilot Performance in instrument flight as a function of the extent and distribution of visible horizon* (Interim Report 71-16-3, Contract N6ori-71, Task Order XVI). Port Washington: Office of Naval Research, Special Devices Center.

1950

Flexman, R. E., Matheny, G. W., & Brown, E. L. Evaluation of the School Link and special methods of instruction in a ten-hour private pilot flight-training program. *University of Illinois Bulletin,* 47(80; Aeronautics Bulletin 8).

Johnson, B. E. *Obedience to rotation-indicating visual displays as a function of confidence in the displays.* Master's thesis in engineering psychology, University ofillinois. [Same as Johnson & Williams, 1949.]

Nicklas, D. R. *The control of aircraft rate of climb by pilots using various altitude instruments.* Master's thesis in engineering psychology, University of Illinois.

Payne, T. A. *A study of the moving part and orientation of symbols on pictorial aircraft instrument displays for navigation.* Master's thesis in engineering psychology, University of Illinois.

Payne, T. A. *A study of the moving part and orientation of symbols on pictorial aircraft instrument displays for navigation* (Technical Report 71-16-6, Task Order XVI). Port Washington: Office of Naval Research, Special Devices Center.

Roscoe, S. N. *Aircraft pilot performance as a function of the extent and magnification of the visible horizon.* Ph.D. dissertation in engineering psychology, University of Illinois.

Roscoe, S. N., Smith, J. F., Johnson, B. E., Dittman, P. E., & Williams, A. C., Jr. *Comparative evaluation of pictorial and symbolic VOR navigation displays in the 1-CA-1 Link trainer* (Report 92). Washington, D.C.: Civil Aeronautics Administration, Division of Research.

Williams, A. C., Jr., & Roscoe, S. N. Evaluation of aircraft instrument displays for use with the omni-directional radio range. *Journal of Applied Psychology, 34,* 123-130. [Abbreviated version of Williams & Roscoe, 1949a.]

1951

Bell, J. M. *A landing display for use with a contact flight simulator* (Technical Report 71-16-7, Contract N6ori-71, Task Order XVI). Port Washington: Office of Naval Research, Special Devices Center.

Fitts, P.M. (Ed.), Chapanis, A., Frick, F. C. Garner, W. R., Gebhard, J. W., Grether, W. F., Henneman, R. E., Kappau(W. E., Newman, W. B., & Williams, A. C., Jr. *Human engineering for an effective air-navigation and traffic-control system.* Washington, D.C.: National Research Council, Committee on Aviation Psychology.

Johnson, B. E., Williams, A. C., Jr., & Roscoe, S. N. *A simulator for studying human factors* in *air traffic control systems* (Report 11). Washington, D.C.: National Research Council, Committee on Aviation Psychology.

Nicklas, D. R., Roscoe, S. N., & Williams, A. C., Jr. *A comparison of pilot performance on four aircraft attitude and heading displays: Conventional, 6N-1a, 6N-1b, and AF48-2* (Technical Report 71-16-9, Contract N6ori-71, Task Order XVI). Port Washington: Office of Naval Research, Special Devices Center. [Not distributed.]

———. Research on synthetic trainers. In *Conference for planning psychological research related to optimum utilization ofB-50 electronic flight simulators.* Lackland Air Force Base: Human Resources Research Laboratory.

Roscoe, S. N. Flight by periscope: I. Performing an instrument flight pattern: The influence of screen size and image magnification. *University of Illinois Bulletin, 48(55;* Aeronautics Bulletin 9).

Seely, E. A. *The effect of combining heading and position information in a single instrument upon aircraft pilot performance in beam bracketing.* Master's thesis in engineering psychology, University of Illinois.

1952

Brown, E. L. *Detailed outline for the evaluation of a pictorial landing display for use with the P-1 contact flight trainer.* Master's thesis in education, University of Illinois.

Flexman, R. E., Roscoe, S. N., & Williams, A. C., Jr. *Evaluation of the 1-CA-2 Link as a contact and an instrument flight trainer* (Unnumbered [8L Contract N6ori-71, Task Order XVI). Savoy: University of Illinois, Department of Psychology, Aviation Psychology Laboratory. [Not distributed; included in expanded form in Flexman et al., 1972.]

Payne, T. A. *A study of the moving part, heading presentation, and map detail on pictorial air navigation displays.* (Human Engineering Report SPECDEVCEN

71-16-10, Contract N6ori, Task Order XVI). Port Washington: Office of Naval Research, Special Devices Center.

Payne, T. A *A study of the moving part, heading presentation, and map detail on pictorial air navigation displays.* Ph.D. dissertation in engineering psychology, University of Illinois.

Roscoe, S. N., Hasler, S. G., & Dougherty, D. J. *Flight by periscope: II. Making takeoffs and landings: The influence of image magnification, practice, and various conditions of flight* (Human Engineering Report SCD 71-16-9, Contract N6ori-71, Task Order XVI). Port Washington: Office of Naval Research, Special Devices Center. [Eventually declassified and published in 1966 in *Human factors.]*

1953

Dougherty, D. J. *The use of visual cues during selected flight maneuvers: A comparison of cues reported as used at two stages of flight training.* Master's thesis in education, University of illinois.

Johnson, B. E. *Vectoring aircraft by radar: The effect of load and speed differences on controllers' performance in a simulated air traffic situation.* Ph.D. dissertation in engineering psychology, University of illinois.

Licklider, J. C. R. (Chair), Clementson, G. C., Doughiy J. M., Huggins, W. H., Seeger, C. M., Smith, C. C., Williams, A C., Jr., & Wray J. *Human factors in the operation and maintenance of all-weather interceptor systems: Conclusions and recommendations of Project Jay Ray, a study group on human factors in all-weather interception* (HFORL Memorandum 41). Bolling Air Force Base: Human Factors Operations Research Laboratories.

Matheny, W. G., Williams, A C., Jr., & Dougherty, D. J. *The effect of varying control forces in the P-1 trainer upon transfer of training to the T-6 aircraft* (Technical Report AFPTRC-TR-53-31). Lackland Air Force Base: Human Resources Research Center.

Muckier, F. A *Transfer of training in tracking as a function of control friction.* Master's thesis in engineering psychology, University of illinois.

Ritchie, M. L. *Transfer of training as a function of task complexity.* Ph.D. dissertation in engineering psychology, University of illinois.

1954

Arnold, J. W., Schlesinger, H., Ritchie, M. L., Williams, A C., Jr., Adelson, M., Hasler, S. G., & Wilkerson, L. E. *Two display designs for presentation of all flight attitudes* (WADC Technical Report 54-316). Wright-Patterson Air Force Base: Wright Air Development Center.

Muckier, F. A, & Matheny, W. G. Transfer of training in tracking as a function of control friction. *Journal of Applied Psychology, 38,* 364.

Paul, W. H., Andrews, F. B., Williams, A C., Jr., Ritchie, M. L. & Hasler, S. G. *Five displays for combining aircraft heading and attitude: Part I. Display designs* (WADC Technical Report 54-156; also identified as AF Technical Report 54-145). Wright-Patterson Air Force Base: Wright Air Development Center.

Payne, T. A, Dougherty, D. J., Hasler, S. G., Skeen, J. R, Brown, R L., & Williams, A C., Jr. *Improving landing performance using a contact landing trainer* (Technical Report SPECDEVCEN 71 16-11, Contract N6ori-71, Task Order XVI). Port Washington: Office of Naval Research, Special Devices Center.

Payne, T. A, & Williams, A C., Jr. Recommended features for pictorial computer displays for air navigation. Appendix to R. E. McCormick & F. S. McKnight. *The type V pictorial computer with automatic chart selection: Part II. Technical and operational evaluation,* pp. 12-16. (Technical Development Report 243). Indianapolis: Civil Aeronautics Achninistration, Technical Development and Evaluation Center.

Williams, A C., Jr., & Adelson, M. *Some considerations in deciding about the complexity of flight simulators* (Research Bulletin AFPTRC-TR-54-106). Lackland Air Force Base: Air Force Personnel and Training Research Center.

Williams, A C., Jr., Ritchie, M. L., Adelson, M., Wilkerson, L. E., Hasler, S. G., Skeen, J. R., & Fogel, L. J. *Poly parametric and vector airspeed indicators* (WADC Technical Report 54-314). Wright-Patterson Air Force Base: Wright Air Development Center.

1955

Adelson, M., Muckier, F. A, & Williams, A C., Jr. Verbal learning and message variables related to amount of information. In H. Quastler (Ed.), *Information theory in psychology: Problems and methods* (pp. 291-303). Glencoe: The Free Press.

Michael, A L. *A conflict interpretation of certain perceptual dynamics.* Ph.D. dissertation in clinical psychology, University of illinois.

Roscoe, S. N. A long range cockpit research and development program: Part II. In *Final report, 1955 USAF Instrument Symposium: Section* IX. *Classified supplement* (pp. 31-42). Moody Air Force Base: United States Air Force.

1956

Skeen, J. R *Some effects of varying control-display relationships in a discrete tracking task.* Ph.D. dissertation in engineering psychology, University of illinois.

Williams, A C., Jr., Adelson, M., & Ritchie, M. L. *A program of human engineering research on the design of aircraft instrument displays and controls* (WADC Technical Report 56-526). Wright-Patterson Air Force Base: Wright Air Development Center.

Williams, A C., Jr., Houston, R C., & Wilkerson, L. E. Simultaneous contact-instrument flight training. *University of Illinois Bulletin,* 53(42; Aeronautics Bulletin 18).

1957

Fitts, P.M., Flood, M. M., Garman, R A, & Williams, A C., Jr. *The USAF human factor engineering mission as related to the qualitative superiority of future man-machine weapon systems.* Washington, D.C.: US Air Force Scientific Advisory Board, Working Group on Human Factor Engineering Social Science Panel.
Roscoe, S. N. The development of integrated instrument display panels at

Hughes Aircraft Company. In M. L. Ritchie & C. A. Baker (Eds.), *Psychological aspects of cockpit design: A symposium report* (Technical Report WADC 57-117, pp. 28-40). Wright-Patterson Air Force Base: Wright Air Development Center.

1958

Deal, O. E., & Williams, A. C., Jr. *Redundant information and the concept of manual control for Dyna Soar I* (Unnumbered). Culver City: Hughes Aircraft Company.

Deal, O. E., & Williams, A. C., Jr. *Special report on Dyna Soar I human factors study: Use of the operator in Dyna Soar I* (Reference 2405/129). Culver City: Hughes Aircraft Company.

———. *Will the pilot become obsolete?* (Reference 4112.40/82). Culver City: Hughes Aircraft Company; Human Factors Engineering Section.

Williams, A. C., Jr., & Hopkins, C. O. *Aspects of pilot decision making* (WADC Technical Report 58-522). Wright-Patterson Air Force Base: Wright Air Development Center.

1959

Muckier, F. A, Nygaard, J. E., O'Kelly, L. I., & Williams, A. C., Jr. *Psychological variables in the design of flight simulators for training* (WADC-TR-56-369). Wright-Patterson Air Force Base: Wright Air Development Center.

Roscoe, S. N., Partridge, A. B., & Heineman, R. E. *AN/ASG-18 fire control subsystem: Human factors data* (Report ASG-18-74-S). Culver City: Hughes Aircraft Company, System Development Laboratories.

1960

Hopkins, C. O., Bauerschmidt, D. K., & Anderson, M. J. *Display and control requirements for manned space flight* (WADD Technical Report 60-197). Wright-Patterson Air Force Base: Wright Air Development Division.

Williams, A.C., Jr., Simon, C.W., Haugen, R., & Roscoe, S.N. Operator performance *in strike reconnaissance* (WADD Technical Report 60-521). Wright-Patterson Air Force Base: Wright Air Development Division.

1961

Hopkins, C. O., Bauerschmidt, D. K., & Roscoe, S. N. *APOLLO display and control subsystem* (Technical Memorandum TM-680). Culver City: Hughes Aircraft Company, Aerospace Group.

Roscoe, S. N., Hopkins, C. O., & Bauerschmidt, D. K. *APOLLO spacecraft displays and controls* (Technical Memorandum TM-691). Culver City: Hughes Aircraft Company, Aerospace Group.

1966

Roscoe, S. N., Hasler, S. G., & Dougherty, D. J. Flight by periscope: Making takeoffs and landings; the influence of image magnification, practice, and various conditions of flight. *Human Factors, 8,* 13-40. [Declassified version of Roscoe, Hasler, & Dougherty, 1952.]

1968

Roscoe, S. N. Airbome displays for flight and navigation. *Human Factors,* 10, 321-332. [Review of display design principles established at APL; reissued in 1990 in M. Venturino (Ed.), *Selected readings in human factors.* Santa Monica: Human Factors Society.]

1971

——— (posthumously). Discrimination and manipulation in goal-directed instrument flight. *Aviation Research Monographs,* 1(1), 1-54.

1972

Flexman, R. E., Roscoe, S. N., Williams, A. C., Jr., & Williges, B. E. Studies in pilot training: The anatomy of transfer. *Aviation Research Monographs* 2(1). [Contains material from Williams & Flexman, 1949c; Flexman, Roscoe, & Williams, 1952.]

Johnson, B. E., & Williams, A. C., Jr. Obedience to rotation-indicating visual displays as a function of confidence in the displays. In S. N. Roscoe & B. H. Williges (Eds.), Three lessons in aviation research. *Aviation Research Monographs,* 1(3), 11-25. [Same as Johnson & Williams, 1949.]

1980

Roscoe, S. N. *Aviation psychology.* Ames: Iowa State University Press. [Contains material from Williams, 1980, and reviews much of the research done by Williams and his students and associates.]

———. Discrimination and manipulation in flight. In S. N. Roscoe (Ed.), *Aviation psychology.* Ames: Iowa State University Press.

1984

Roscoe, S. N. Judgments of size and distance with imaging displays. *Human Factors, 26,* 617-630. [Based primarily on previously unpublished research done in 1950 at APL under the mentorship of A. C. Williams, Jr.]

Ross A. McFarland, 1901-1976

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When the Society of Engineering Psychologists, Division 21of the APA, was formed in 1957, Ross McFarland had already published many papers and two books of encyclopedic scope dealing with human factors (McFarland, 1946, 1953). His research in the field, an ilnportant part of the work his books covered, began in 1927, just 30 years before the field was defined by the formation of Division 21. In this essay, I will describe not only McFarland's contributions, but also his ventures, methods, and successes as a human factors pioneer.

Background

Ross McFarland was a second-generation scholar. His father James attended McGill and Presbyterian colleges in Montreal, the College of Physicians and Surgeons in Chicago, Union Theological Seminary in New York, and McCormick Theological Seminary in Chicago. James McFarland was a Presbyterian minister in Colorado for 20 years, and Ross was born in Denver in 1901.

Upon the death of his father when Ross was five, his mother moved the family to Parkville, Missouri. At Park Academy and College, a youth needed only ability and willingness to work (on buildings as well as studies) to get a college education. Ross completed his sophomore year at Park College in 1921. He went on to the University of Michigan and finished the baccalaureate in June 1923. There his course work centered on political economy and political science.

At Michigan, Ross was very active in YMCA and similar activities. He learned of a new organization that was providing financial support for graduate students. They wanted persons who would prepare for a university career teaching the philosophy and psychology of religion. Ross applied for a fellowship to study at Harvard for a doctorate in psychology. In his application he said, "I go at things rather slowly and steadily. I am determined, however, in all that I set out to accomplish

and I do not give up easy ... I have always had to work hard for the things I have obtained."

Ross was granted a fellowship by the National Council for Religion in Higher Education for a year of study at Harvard. The council was a new organization whose prilne mover was Charles Foster Kent of Yale. McFarland's grant was called a Kent Fellowship, and he was notified of his selection in a letter from Professor Kent himself.

The Kent Fellowship was renewed and extended through the completion of doctoral studies at Harvard. Along the way; Ross engaged in several activities of the council, including several months of service as the council's field secretary. The council arranged another Kent Fellowship for him to study at Cambridge for a year in the laboratory of Frederick C. Bartlett. While Ross was at Cambridge, the council's director negotiated with Columbia University to get a faculty position for him. Ross was active with the organization for many years.

Graduate Study at Harvard

McFarland was a graduate student at Harvard from the fall of 1923 to the spring of 1927. At Harvard he took seven psychology full courses, nine psychology half courses, and two philosophy half courses.

The Harvard courses were interspersed with courses he took and courses he audited at Yale from the fall of 1924 to the spring of 1927. Professor Kent had advised him, "I have been investigating, throughout the summer, the facilities offered by the various universities of America and England for the doctorate in the Psychology and Philosophy of Religion. Frankly, it is largely a virgin field and the opportunity for the properly qualified man or men is great. After considerable thought, therefore, I have a strong conviction that you could do no better than register in the Yale Graduate School and Divinity School, for at least one year." Ross's Yale courses were in the philosophy of religion and related subjects.

McFarland took the preliminary examinations at Harvard in May 1925 and had completed the research for his dissertation by the spring of 1927. He was awarded the Ph.D. on June 20, 1929, with specialty in psychology. His dissertation was under the direction of E. G. Boring. A variety of tests of mental ability were administered to five other graduate students (Donald MacKinnon was one). Ross timed the performance on each test and ranked the five on each test. He examined the consistency of the rankings and concluded that the relative speed of response was characteristic of the individuals.

He published the extensive literature review and problem definition for his dissertation :in 1928 :in the *Psychological Bulletin;* the description of the experimental work was published :in 1930 :in *The Journal of General Psychology* (McFarland, 1928, 1930).

A Research Student at Cambridge

From October 1927 to the spring of 1928, McFarland was at Trinity College, Cambridge University. He held the title of research student and worked under the supervision of Frederick C. Bartlett. As he later described his work there, "In 1927-28 I carried on a series of experiments in the Psychological Laboratory in Cambridge, England in an attempt to determine the psychological effects of oxygen deprivation. Human subjects breathed gas mixtures corresponding to the oxygen percentages at high altitudes. During each experimental hour the subjects were given tests involving simple and complex mental reactions, neuro-muscular control and higher mental processes involving reasoning and memory." Ross returned to the United States on a student tour from June to September through Egypt, Arabia, Iraq, India, Thailand, China, and Japan.

The work at Cambridge resulted in a monograph on the psychological effects of anoxia (McFarland, 1932). The work comprised 135 pages and carried a bibliography of 191 items. The first part contained "a fairly extensive review of the evidence recorded in various fields of research.... The second part... deals with an experimental study carried on in the Psychological Laboratory at Cambridge, England. Simple sensory and motor responses are not seriously impaired until the Subject approaches collapse from Oxygen want and then the loss appears to be fairly sudden. The choice reactions, on the other hand, appear to be impaired at higher percentages of Oxygen than the simple reactions."

Columbia University

Ross McFarland gave his first lecture as instructor in psychology at Columbia University on the September 27, 1928. At Columbia until 1937, he investigated the dependence of the central nervous system upon a normal supply of oxygen, glucose, and other constants. As he recalled, "I was able to continue with research work along with my lectures to pre-medical students ... in collaboration with a number of physicians at the College of Physicians and Surgeons of Columbia University, I was able to study a wide range of problems ... directed

toward a better understanding of the role of oxidation :in mental and emotional disorders, especially the psychoneuroses and schizophrenia" (Hinsie, Barach, Harris, Brand, & McFarland, 1934).

During the summer terms from 1930 to 1934, Ross was :in Geneva, Switzerland, as lecturer :in the School of International Studies.

Expedition to the Andes

In 1935, the Fatigue Laboratory of the Harvard Graduate School of Business assembled a group of 10 scientists from several disciplines for a scientific expedition to the Andes mountains. The objective was to study the characteristics of natives who lived routinely at very high altitudes and compare them with members of the expedition, who represented humans normally living at much lower altitudes. Ross McFarland was chosen to be the team member to measure behavioral responses to the variations :in altitude.

After the group's stay in the mountains, Ross and a colleague accepted an invitation from Pan American Airways to study rapid ascents of altitude by airplane on trans-Andean flights and compare those results with more gradual ascents by railway in the same region of South America. Ross remembered, "This was my first contact with Pan American Airways, and my interest :in aviation developed from these experiments."

For the studies of rapid ascent by airplane, Ross used a simple procedure. He and a colleague mixed drinks for themselves, with carefully measured alcoholic content, then took blood samples and gave handwriting and other tests at timed :intervals. Formal reports of results of the expedition were published in 1937. The other members of the team wrote one article each, and Ross produced four papers, each a substantial contribution (McFarland, 1937b, 1937c, 1937d, 1937e).

A Laboratory to Study Altitude Effects

Following the expedition to the Andes, McFarland obtained funding from the Bureau of Air Commerce to establish a laboratory at Columbia to investigate systematically the effects of oxygen deprivation as found in flying at altitudes. "We established a laboratory for this purpose at Columbia University with a staff of six assistants in physiology and biochemistry. We made a systematic analysis of the effects of oxygen want during rapid and slow ascents to simulated altitudes varying from 10,000 to 20,000 feet. In this investigation, we established for the first time evidence that the average unacclimatized person may be significantly affected by oxygen want at altitudes as low as 10,000 feet" (McFarland, 1938).

In 1936 McFarland was appointed medical coordinator for Pan American Airways, a post he held until1952. In this capacity he helped establish the complement of required medical services for the airline, then helped select and train physicians and other required personnel. He said, "I have served as a Consultant to Pan American Airways in organizing their medical program throughout the System. I have. selected the Flight Surgeons and assisted in organizing the Flight Surgeon's laboratories at Treasure Island, Brownsville, Miami and New York" In the summer of 1937 he carried out for Pan American a systematic investigation of the effects of long flights at altitudes of 8,000 to 12,000 feet on their trans-Pacific operations (McFarland, 1937e).

Harvard Fatigue Laboratory

In 1937, McFarland moved from Columbia to Harvard, where he became assistant professor of Industrial Research in the Fatigue Laboratory, a part of the Graduate School of Business. From nearly the beginning of his service at Harvard, Ross maintained assistance in building up bibliographic information. He said in 1940, "During the past three years I have collected one of the most extensive bibliographies in the field of Aviation Medicine. I have had a research assistant working full-time for three years at the New York Academy of Medicine briefing the results of actual experiments in the field of Aviation Medicine and copying the experimental data. This source of material comprises one of the most extensive bodies of factual data now available in this field. It comprises approximately eight large volumes of typewritten material."

Harvard Business School, Division of Research

In 1939, McFarland's assignment was changed from the Fatigue Laboratory to the Division of Research in the School of Business as assistant professor of industrial research. He still maintained a good deal of contact with the Fatigue Laboratory.

He began a study of the physiological and psychological characteristics of 200 Pan American pilots at the Treasure Island Base. A study was intended to enhance Pan Am's pilot selection technology (McFarland, Graybiel, & Liljencrantz, 1939). Associated with him in this project were Ashton Graybiel, Eric Liljencrantz, and Arnold Tuttle. Graybiel was a

Harvard research cardiologist, Liljencrantz was medical director of Pan American Airways, and Tuttle was medical director of United Airlines. McFarland and Graybiel were already good friends as well as research colleagues; they were to have a long-enduring personal and professional association.

In addition to the study of airline pilots, Ross began a study of student pilots in the Civil Pilot Training Program. In 1940, he said, "I have organized a new laboratory and research staff at Harvard-under the auspices of the National Research Council and Civil Aeronautics Authority. We are studying the 200 student pilots in this region who are learning to fly in the CAA Civilian Training Program. In addition to the studies of the laboratory, we are working out more objective methods of rating student flying performance while in flight. A new flight analyzer has been developed for this purpose. I am also serving on the Executive Committee of the National Research Council-CAA Committee on the Selection and Training of Civilian Pilots in organizing this program throughout the United States."

It was his service on this committee that led to his being in Pensacola in the summer of 1940 to look into the problems of selection and training of naval aviators. As he defined the problems found there, "At the present time a large number of the student pilots in the military services (estimated at 50% or over) are grounded before completing their course of training. Also a large number of the accidents which occur during or after the training period are attributed to human errors. It is obvious that more reliable tests at the time of original selection might result in a great saving of time, effort and money."

Ross wrote a proposal for a study to begin immediately to define the characteristics of in-coming student pilots and experienced flight instructors, using the kind of tests that the committee had used in studying civilian pilots. "In order to successfully apply the tests to military aviation, however, a large group of pilots should be studied at the beginning of their course and followed for a period of time thereafter." It was proposed that the study be conducted under the auspices of the Harvard Fatigue Laboratory by "a group of scientists from the Harvard Medical School and Fatigue Laboratory, the Dartmouth Eye Institute, and others associated with the Committee on the Selection and Training of Pilots of the National Research Council."

"Three of those planning to go to Pensacola will be members of the U.S. Naval Reserve (Drs. [Alexander] Forbes, Graybiel, and McFarland)." To facilitate the study, Ross was called to active duty as a lieutenant commander. He wrote a progress report on the Pensacola Project in September 1940 that stated, "We have completed (Aug. 30) the tests on 275 cadets and 75 :instructors. We feel encouraged over the results of our study for already we have detected five pilots who are extremely poor :in neuromuscular coordination and lack the essential native ability to fly. Three pilots have manifested advanced cardiac failure, :in the circulatory tests and electrocardiograms. Seven pilots have revealed epileptoid types of behavior and have become unconscious during the metabolism test and have shown striking abnormalities :in brain waves."

Although Ross went back to Harvard in the fall the study continued. By May of 1941, 800 cadets and 100 instructors had been tested. A "F:inal Summary Report" (McFarland & Franzen, 1944) was by no means the last of the project. A follow-up study :in 1965 examined what was then called the Thousand Aviator Study (Oberman, Mitchell, & Graybiet 1965). They cited follow-up studies done :in 1951, 1957, and 1963. A 40-year follow-up study was reported :in 1986.

On May 25,1942, McFarland returned to Park College to receive the honorary degree of doctor of science. At the time he was still an assistant professor. He titled his address "The Impact of Aviation on Modem Life" (McFarland, 1942). In that address he gave the other midwesterners a glimpse of what he had learned about aviation, "Aviation is a new frontier of human endeavor which will profoundly influence the future course of events. Furthermore, it originated :in our day and it belongs to our generation. Aviation typifies the rapidly changing physical and social environment. It illustrates vividly how technological progress has exceeded the limits of human adaptability, where further advances require greater knowledge of man himself."

He also gave an overview of what he considered then to be the human factors :in aviation, "The human problems :in aviation may be divided essentially :into two parts, the first, relating to the questions of placement and selection, a general problem throughout all :industry, and the second, to the physiological and psychological limitations :in a field which has imposed great stresses both as regards the machine and the environment."

From November of 1943 to February of 1944, Ross served as a civilian operations analyst for the 13th Air Force, studying combat fatigue :in air and ground forces. Based :in the Solomon Islands, he made flights to New Caledonia, New Zealand, and Australia. He stated :in the 1968 edition of *Modern Men of Science* that it was during these :investigations that he became :interested :in the problems of designing equipment to meet human capabilities.

In 1943, McFarland received a grant from the Lockheed Aircraft Corporation to study human factors :in air transport design (McFarland,

1945). This large report was addressed to design engineers and drew upon the vast bibliographic files that Ross and his assistants maintained. Most of the material was addressed to issues of designing transport aircraft to provide a suitable environment for crew and passengers. In 1946 McFarland produced a much larger volume also addressed to engineering designers of air transport aircraft (McFarland, 1946). In the Foreword, Ross stated,

> During the past ten years the author has had an opportunity to fly over the major air transport systems of the world, including flights to three of the combat zones. During this time it has been possible to make first-hand observations of some of the problems encountered in flying various types of aircraft, including both land planes and flying boats. In some cases it has been possible to carry out controlled studies in flight, while some of the problems have been investigated in the laboratory. In carrying out these investigations relating to the human problems in air transportation, a profound respect has grown up for the role of the aeronautical engineers in the design and construction of the modern air transport as it is known today.
>
> In the succeeding pages of this study, an attempt has been made to report some of the observations relating to the human factors in flying influencing both the air crews and the passengers.

The book received wide acclaim; the *Boston Traveler* on November 22, 1946, stated, "The volume is certain to command the close attention of the aviation :industry, and is likely to be an influence in aircraft construction for some time to come."

In September of 1947 Ross received the Longacre Award for Outstanding Scientific Contributions to Aviation Medicine at the Eighteenth Annual Convention of the Aero Medical Association of the United States. At the same time he was made a Fellow of the Aero Medical Association, along with six other members of the society.

Harvard School Of Public Health

In 1947, Ross was made assistant professor of :industrial hygiene in the Harvard School of Public Health, where he was promoted to associate professor in 1949. In 1948, he began working on a series of grants for research, and later he taught highway transport safety. This work was supported by Liberty Mutual Insurance Co., the National Association of Automotive Mutual Insurance Companies, American Trucking Association, and National Association of Motor Bus Operators (McFarland, 1951, 1952a, 1952b, 1952c, 1952d, 1952e).

An objective of this program was to consider current practice with reference to the principle of designing equipment to suit the needs of the human operators. Current vehicles were examined with regard to such issues as location and design of electrical switches, lack of a standard shift pattern, and failure to provide adequate seat adjustment. To illustrate the problems being addressed, references were made to aircraft research and aircraft accidents.

In 1949, Ross was made a member of The President's Conference on Industrial Safety. In a paper that was included as an appendix to the report of the conference he stated, "In discussing the effective integration of the worker and the machine, primary consideration is given to display and control problems. The former is concerned with the imparting of information by various sense organs in regard to the functioning of the machine or the equipment. The latter relates to the location and use of controls and levers in the performance of duties. A great deal of the experimental data in this field has come from aeronautical research, but the principles can be applied to other industries" (McFarland, 1949).

Although Ross maintained an active social life, he was a bachelor until he was 49. In 1950 he married Emily Frelinghausen Bilkey and, in the same year, he initiated a program in aviation health and safety in the Harvard School of Public Health. The program trained flight surgeons and other medical professionals.

In 1951McFarland began work on a series of research grants from the US. Army Surgeon General's Commission on Accidental Trauma. These grants carried the title "Human Factors in Vehicular Design and Operation, with Special References to Accidents." In a Harvard Public Health *Alumni Bulletin* he noted, "A broad research program in accident prevention is currently being conducted at Harvard," among the issues addressed were those of desigrling vehicles to suit the characteristics of their human operator (McFarland,1952e).

His research group assembled a strong multidisciplinary team to investigate accidents in much more depth than is usual, including engineering structural analysis and autopsies of victims. They also built calibrated driver stations to evaluate body support dimensions and reach distances. With this work under way, Ross began writing about human engineering (McFarland, 1954a, 1954b). His expertise continued to lie in the areas of environmental effects on human performance.

His second major book (McFarland, 1953) was written for aviation physicians and safety directors. In introducing the book, Ross wrote, "There is a widely scattered literature on various individual problems, such as the effects of altitude, acceleration, noise, and bration but no

systematized treatment designed for the aeronautical engineers and the air line operators. This book goes beyond the narrow confines of academic disciplines and for the first time attempts to unify and interpret the data so that it can be given practical application. It is also unique for, unlike several other books dealing with various aspects of aviation medicine, it is directed not toward the flight surgeon alone but to the aircraft designer and operator as well."

In 1956 McFarland received two grants to prepare chapters for the forthcoming *Human Engineering Guide to Equipment Design* (McFarland, 1963a, 1963b), one from the Office of Naval Research and one from the US. Air Force's Wright Air Development Center.

In 1957 McFarland received a grant from the Guggenheim Foundation for research and teaching in aviation health and safety. The $250,000 award was to provide support for five years. A year later he became professor of environmental health and safety in the School of Public Health, a post he held until1962.

Interaction with Paul Fitts

Correspondence between Paul Fitts and Ross McFarland reveals the men's similarities and their differences. In 1947 Ross asked to be put on Paul's distribution list to receive reports from the Aero Medical Laboratory at Wright Field. Paul responded that he had done so and said, "I hope that we can keep in touch with each other and that you will stop by to visit our laboratory occasionally."

In 1949 Fitts wrote to say that he was to be teaching a course in aviation psychology the next quarter. In that connection he wondered about the status of the second volume in the field that McFarland had worked on for the past few years. McFarland replied that the book was to be at the printers on January 1 and attached an outline.

In 1960 Fitts sent McFarland an announcement of his Ph.D. program in engineering psychology at the University of Michigan. In reply, Ross noted that the program was a comprehensive one and that "I am sure that persons trained in this intensive way should be able to make an outstanding contribution to this field in which we are mutually interested." He added, "I am still developing the aviation medicine program, and as you will see from the attached pamphlet, we have trained 75 physicians thus far. I only have one or two engineers each year, but they are making substantial contributions in the human factors field."

Also in 1960 Fitts sent McFarland a draft of a report oh training in engineering psychology, which was being prepared by a committee of APA Division 21. He asked for comments. Ross replied, "I am sorry about the delay in answering your letter in regard to making comments on 'Training in Engineering Psychology/ to be published in the *American Psychologist.* I believe the sections on graduate courses and the training of instructors are very good indeed. My only comment would be the rather cursory reference on page 11 to disciplines other than psychological. Some of the engineering psychologists in this field will be excessively restricted in their grasp of problems if they are not D;lore thoroughly versed in certain aspects of physiology, anatomy, and other biological sciences, as well as psychology and engineering."

The Guggenheim Center for Aerospace Health and Safety

In 1962 the Guggenheim Foundation made a gift of $750,000 to Harvard University to establish the chair and center of Aerospace Health and Safety in the Harvard School of Public Health. The gift was to cover a 10-year period. Ross McFarland was named the first director of the center and the first occupant of the Florence and Daniel Guggenheim Chair of Aerospace Health and Safety. He held this post throughout the 10-year period, becoming part time after his retirement in 1969. Then, in 1972, he became emeritus director of the center. Of the center's program it was said in 1972, "Professor McFarland and his colleagues at the Harvard School of Public Health have trained over 200 physicians in aerospace medicine during the last 10 years. Many are leaders in the Man-in-Space program."

In 1963, Ross was honored by the Ergonomics Research Society of Great Britain as one of the persons who had done most for the safety of those who travel by air or automobile.

On April2, 1964, McFarland received the honorary degree Sc.D. from Rutgers University at the dedication of Smithers Hall, the Rutgers Center of Alcohol Studies. On October 30, 1965, he received the same degree from Trinity College in Hartford, Connecticut, at the groundbreaking of the new Life Sciences Center.

In 1966 McFarland and his colleagues at the School of Public Health, wrote yet another book (Damon, Stoudt, & McFarland, 1966). The volume was awarded the Harvard University Press Faculty Prize.

On August 30, 1968, McFarland received the Franklin V Taylor Award from the Society of Engineering Psychologists (APA Division 21) for Outstanding Contributions to the Field of Engineering Psychology. In 1970 he received the Exceptional Service Award of the U.S. Air Force for his "unique contribution during the period of 1937 through 1969 in

Aerospace Health and Safety and related fields of human factors engineering."

In 1969-1970 McFarland was president-elect of the Human Factors Society, followed in 1970-1971 with a term as president. In 1970-1971 he was also vice president of the Aerospace Medical Association and in 1971-1972 served as president of Division 21 of the American Psychological Association.

In 1972 Ross became emeritus director of Guggenheim Research and Teaching Center for Health and Safety, a title he retained until his death in 1976 at age 75. In 1978 Emily McFarland gave Ross's library and papers to Wright State University School of Medicine with the stipulation that the material be made available for scholars, researchers, and students. The Fordham Library of Wright State organized the material and published a catalog of the library and an inventory of the manuscripts (Hoffman, 1987; Hoffman & Ritchie, 1987). The collection serves the university's aerospace medicine program, the human factors engineering undergraduate and graduate programs, and the human factors psychology undergraduate and graduate programs.

References

Damon, A., Stoudt, H. W., & McFarland, R. A. (1966). *The human body in equipment design.* Cambridge: Harvard University Press, 1966, 1971.

Hinsie, L. E., Barach, A. L., Harris, M. M., Brand, E., & McFarland, R. A. (1934). The treatment of dementia praecox by continuous oxygen administration in chambers and oxygen and carbon dioxide inhalations. *Psychiatric Quarterly, 8,* 34-17.

Hoffman, M.A. (1987). Ross A. McFarland Collection in aerospace medicine and human factors engineering: 1. catalog of the library. Wright State University School of Medicine.

Hoffman, M. A., & Ritchie, R. A. (1987). Ross A. McFarland collection in aerospace medicine and human factors engineering: 2. Inventory of the manuscripts. Wright State University School of Medicine.

McFarland, R. (1928). The role of speed in mental ability. *Psychological Bulletin,* 25(10), 595-612.

McFarland, R. (1930). An experimental study of the relation between speed and mental ability. *Journal of General Psychology,* 3(1), 67-97.

McFarland, R. (1932). The psychological effects of oxygen deprivation (anoxia) on human behavior. *Archives of Psychology* (145).

McFarland, R. (1937a). The effects of prolonged exposures to altitudes of 8,000 to 12,000 feet during trans-Pacific flights. *Journal of Aviation Medicine, 8.*

McFarland, R. (1937b). Psycho-physiological studies at high altitude in the

Andes: I. The effects of rapid ascents by aeroplane and train. *Journal of Comparative Psychology,* 23(1), 191-225.

McFarland, R. (1937c). Psycho-physiological studies at high altitude in the Andes: II. Sensory and motor reactions during acclimatization. *Journal of Comparative Psychology,* 23(1), 227-258.

McFarland, R. (1937d). Psycho-physiological studies at high altitude in the Andes: ill. Mental and psycho-somatic responses during gradual adaptation. *Journal of Comparative Psychology,* 23(2), 147-188.

McFarland, R. (1937e). Psycho-physiological studies at high altitude in the Andes: N Sensory and circulatory responses on the Andean residents at 17,500 ft. *Journal of Comparative Psychology,* 23(2), 189-220.

McFarland, R. (1938). *The effects of oxygen deprivation (high altitude) on the human organism* (Report No. 13, U.S. Bureau of Air Commerce).

McFarland, R. (1942). *The impact of aviation on modern life.* Parkville: Park College Press.

McFarland, R. (1945). Factors in the design of air transport planes influencing comfort and safety in flight. Cambridge: Harvard University, Graduate School of Business Administration, Division of Research.

McFarland, R. (1946). *Human factors in air transport design.* New York: McGraw-Hill.

McFarland, R. (1949). The role of human factors in industrial accidents. Appendix 1 to William P. Yant *The president's conference on industrial safety.*

McFarland, R. (1951). Human factors in highway transport safety. Presented to the American Mutual Alliance, Miami.

McFarland, R. (1952a). Human factors in highway safety. *Harvard Public Health Alumni Bulletin.*

McFarland, R. (1952b). Human factors in highway safety. *Road User Characteristics* (Highway Research Board, Bulletin 60). Washington, D.C.

McFarland, R. (1952c). Human factors in highway safety. *Bests Fire and Casualty News,* 37-38, 132-140.

McFarland, R. (1952d). Human factors in highway-transport safety. *Harvard Public Health Alumni Bulletin,* 11-16.

McFarland, R. (1952e). Human variables in the design and operation of highway transport equipment. Society of Automotive Engineers, Preprint No. 717.

McFarland, R. (1953). *Human factors in air transportation.* New York: McGraw-Hill.

McFarland, R. (1954a). Human engineering: A new approach to driver efficiency and transport safety. *Society of Automotive Engineers Transactions, 62,* 335-345.

McFarland, R. (1954b). Human-engineering aspects of safety. *Mechanical Engineering,* 407-410.

McFarland, R. (1963a). Anthropometry. In *Human engineering guide to equipment design.* New York: McGraw-Hill.

McFarland, R. (1963b). Effects of environment on human performance. *In Human engineering guide to equipment design.* New York: McGraw-Hill.

McFarland, R., & Franzen, R. (1944). *The Pensacola study of naval aviators. Final summary report* (Report No. 38). Washington, D.C.: Civil Aeronautics Administration, Division of Research.

McFarland, R., Graybiet A, & Liljencrantz, E. (1939). An analysis of the physiological and psychological characteristics of two hundred civil air line pilots. *Journal of Aviation Medicine, 10.*

Oberman, A, Mitchell, R. E., & Graybiet A (1965). *Thousand aviator study methodology* Joint Report, U.S. Navy School of Aviation Medicine, U.S. Public Health Service, NASA).

George Edward Briggs, 1926-1974

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George Briggs, a fascinating and brilliant figure in the history of applied experimental and engineering psychology, died just as his most lasting contribution was coming to fruition. This work-a program of research on the binary classification task (BCT)-was science at its best, a combination of clear logic and rigorous experimentation applied systematically to an important problem. It was the kind of research that one rarely encounters outside of textbooks. It was also in many ways a reflection of the man-but not the *whole* man. George was anything but one-dimensional in his personal or professional life, yet he had a rare ability to concentrate fully and to dedicate himself completely to the issue at hand, whatever that issue might be. He was not a half-way person. In a sense, his model of the processes underlying binary choice-essentially a linear stage model-is a fitting metaphor for his life.

I knew George as a mentor, colleague, and friend, and I valued him immensely in each of these roles. Because *it* is to be exclusively "professional" in its orientation, the following account cannot do him full justice. To anyone fortunate enough to have know him well, George Briggs was far more than a collection of archival materials and entries on a CV He had an impact on anything and anybody he touched, simply by virtue of the strength of his personality. His influence on the field was profound and lasting, but it occurred as much through the direct engagement of minds as *it* did through formal channels of communication.

Beverly Briggs, David Martin, and Samuel Mudd each provided me with valuable documentation on George's career and accomplishments. It is worth noting in this regard that Sam Mudd was sufficiently impressed with George's systematic approach to BCT that he wrote an entire book on *it* (Mudd, 1983). Not bad for a program that spanned only about six years out of a career that produced many other accomplishments-and ended much too soon!

The Life and Times of George Briggs

George Edward Briggs was born in Columbus, Ohio, on May 27, 1926. His family had deep roots in the area, as evidenced by the town of Briggsdale, Ohio, which was named after one of his forebears. Most of those closest to him regarded him as a confirmed midwesterner and, indeed, apart from his stint in the Navy, almost his entire life was spent there. Then, in 1973, much to everyone's surprise, he moved to Las Cruces to head up the New Mexico State University psychology department. The idea of George in the desert struck most of us as totally incongruous, but as so often happened, "most of us" were dead wrong. He adapted immediately and came to love the desert and his new southwestern life-style with a passion. What we took as a permanent condition was merely an initial stage, and New Mexico represented the transition to a new one. His life seemed to unfold in stages, with transitions known only to him. Changes in his thinking, as in his career or life situation, thus always seemed abrupt, complete, and a bit impulsive-and always took everyone by surprise. In actuality, they probably were far more reasoned than we imagined.

George was broadly educated in experimental psychology, graduating with distinction from Ohio State University (OSU) in 1949, continuing on for the master's (which he earned a year later), and completing the Ph.D. in 1953 at Wisconsin. This was followed by an NSF postdoctoral fellowship at Northwestern. His first mentor at Ohio State was Arthur Melton, whom he often credited with attracting him to the field as an undergraduate and stimulating his interest in human learnmg. By going to Wisconsin and then to Northwestern, two of the foremost guardians of the functionalist tradition, George assured himself a solid foundation in methodology and the content of human learning. He also cultivated an appreciation for the painstaking, systematic, empirical approach to research and the value of hard work-a philosophy he never compromised. Although his perspective shifted to other facets of human performance, applied as well as basic, his belief in the soundness of a rigorous attack on a problem was never shaken.

His first permanent employment was back at Ohio State as a research associate in Paul Fitts's Laboratory of Aviation Psychology (APL). Engineering psychology and human factors were just coming into their own as recognized fields, Fitts was among the founders of both, and his laboratory was definitely one of a handful of places to be for anyone wishing to join in the excitement. Paul recognized immediately the talent he had in George and very quickly shifted primary responsibility for one of the two principal research activities in the laboratory, a large program in skill learning and performance, to him.

When I joined the lab in 1957, George was generally viewed as its unofficial second-in-command and, given Paul's hectic travel schedule, assumed much of the burden of day-to-day operations. For new Ph.D.s such as I, as well as the cadre of bright and eager graduate students who were always around, George was role model and mentor. For some reason, he accepted me as a colleague despite my total ignorance of the motor skills area and the fact that I had been hired primarily to work on other kinds of projects.

He expected total dedication from anyone working with or for him and had absolutely no tolerance for carelessness, sloth, or incompetence. Committed students were somewhat in awe of him but would work diligently to maintain his approval, recognizing that he asked far less of them than he did of himself. Less committed students feared him-and usually didn't last too long. Although not technically a student, I felt like one and considered working with George a special learning opportunity, which is probably one reason he accepted me despite my ignorance. (I recount these personal reflections not to insert myself into the story, but merely to convey a sense of how George influenced people. One did not come away from even a casual interaction with him unaffected. The values and habits that he instilled in his many students had a profound effect on them, and through them on the field for years to come.)

Tracking and Skills Research

The first stage of his career was spent mainly in the perceptual-motor skills area. The paradigm of choice at the time was the continuous tracking task, and the predominant explanatory concepts were drawn largely from the engineering literature, notably control theory. The systems of greatest practical interest were those driven by continuous control processes such as air, land, and sea vehicles, in which control could be vested in a human, a machine (servo), or some combination (machine aiding). In this view, human performance and suggestions for improving it were conceptualized in terms of analog models. Burning research issues centered around identifying, in precise quantitative terms, how skilled controllers function as servo mechanisms, where their limitations are (so as to compensate through design), and how the skill develops with practice (so as to optimize learning and transfer through training). George was at the forefront of this work He educated himself in the relevant engineering domains to the point that he could converse knowledgeably and in depth on these issues with the engineering community *in their language.* Because of this, he was able to make the difficult connection between psychological research and engineering practice to the benefit of both. He helped clarify methodological issues, as in the classic 1957 *Psychology Bulletin* article with Harry Bahrick and Paul Fitts on measurement artifacts in tracking research (Bahrick, Fitts & Briggs, 1957), and added substantially to the empirical knowledge base with more than a score of significant publications.

Most important, he brought the engineering models and their implications to psychology through chapters in Melton's *Categories of Human Learning* (1964), Bilodeau and Bilodeau's *Principles of Skill Acquisition* (1969), and his coauthored *Annual Review* article (Melton & Briggs, 1960). He was among the first to appreciate the limitations of this approach for modeling human performance and to caution against its misuse. He saw the practical and heuristic value in engineering models but realized that they could never provide a satisfactory theoretical account for perceptual-motor skill because its parameters were always changing.

While engaged in this tracking work, George anticipated several important later developments in human performance and cognitive psychology. For example, studies on over-learning effects and his progression-regression hypothesis were precursors to the now-popular concept of automaticity. And he was among the first researchers to appreciate the potential of the dual-task paradigm for measuring mental capacities.

Simulation, Big Science, and Research Management

By the early 1960s, George's professional life had taken a dramatic new turn. Following Paul Fitts's departure to the University of Michigan in 1958, George assumed full responsibility for directing APL and the doctoral program in engineering psychology. He was also awarded a tenured associate professorship in the psychology department. This new role forced him to become involved in all the ongoing work of the laboratory, including its principal source of income, a large-scale program in air traffic control (ATC) simulation sponsored by the Air Force (it was managed by Jerry Kidd).

The ATC program had been going on for some time; was widely acclaimed as a unique and productive facility for studying a variety of social, procedural, and display variables in a realistic setting; and had been growing about as fast as the motor skills program had been declining. But by 1962 it was in trouble because the federal government had decided to move all responsibility for air traffic control, civilian and military, R&D as well as operations, to the FAA. George was faced with the unenviable prospect of running the APL farm minus its prize cash cow.

Somehow, with the help of Jerry and Air Force (AMRL) sponsors, who considered the APL connection too valuable to lose, George was able to broker a deal whereby the Air Force support for simulation research was not only preserved but also dramatically increased. The OSU administration was a player, as was a leading computer manufacturer. The former saw an opportunity for the university to get into the computer game; the latter saw a valuable testbed for trying out and promoting state-of-the-art technology. George Briggs undoubtedly had a lot to do with their seeing things that way. Characteristically, he had thrown himself completely into this new venture-a very delicate exercise in management and persuasion-and had come out a winner. In the process, he helped establish the first computer center at OSU, doubled the size of APL, and redirected its principal thrust into a completely new domain: complex information processing and decision systems. Working in close cooperation with Ward Edwards's group at Michigan and several other laboratories, APL eventually developed a military threat diagnosis simulation that was as productive and widely recognized as its ATC predecessor.

The global vision and successful selling job, however, were but a small part of the formidable task of shifting *API:*s orientation from air traffic control to military decision systems. A computer-based simulator had to be defined and built; a research program planned and executed; new scientific and support expertise acquired-all more or less concurrently. Patience was not among George's outstanding virtues, yet he was forced to endure several years of frustration as the newly assembled team of researchers and computer specialists struggled with the impossible task of building customized software from scratch for a system whose requirements changed almost daily. The experience did, however, move his research interests for a time from the relatively pure context of the motor skills laboratory to the more applied domain of the complex multiperson system, and he published several papers in this area.

Pure Administration

The successful transformation of APL also established George's reputation as an administrator, particularly in computer applications, and served as a springboard into a new but short-lived career in the

university's central administration. From 1963 to 1966 he served as associate to the vice president for research, Alfred Garrett, and in this capacity presided over the continued evolution of Ohio State's computer facility. Thus, in a very real sense, The Ohio State University entered the computer age on the financial shoulders of a social science (psychology) led by an experimental psychologist (George Briggs). Let those who persist in denigrating the "soft sciences" explain where the "hard scientists" and engineers were when the computer revolution reached OSU!

By the mid-1960s George was beginning to tire of the more banal aspects of administration and longed to return to the excitement of the laboratory. However in what area and capacity? His sojourn into relatively applied "big science," where one's research is constantly at the mercy of funding sources, computer gurus, and sophisticated but fickle equipment, had left him cold. On the other hand, what remained of the rapidly shrinking motor skills area had gravitated across the Atlantic and into fields such as physical education. It was not a viable option for the start of a new career.

Choice Reaction Time and New Mexico State

George solved the problem in a very characteristic, but for anyone else unusual, way. He simply went to the library and to his files, searched intensively, and made a rational choice. What attracted his attention was Saul Sternberg's revival of mental chronometry. Here was an elegant methodology with possibilities for precise quantification of important mental functions that could be managed by an individual researcher with modest funding and a small cadre of graduate students. And it was perfectly suited to the functionalist research style he had cultivated and pursued so successfully before wandering into the swamp of big science. With psychology on the brink of its cognitive revolution, what better route to a rewarding future?

George returned to the OSU faculty in 1967, enlisted a couple of students in the cause-notably Jim Swanson, who turned out to be an extremely bright and eager disciple-and set out to conquer some of the nagging unresolved problems that were limiting the explanatory power of the revived choice reaction time (CRT) paradigm. Although it spanned only six years, this final stage of his career resulted in 14 papers that advanced the methodology and added significantly to our understanding of key cognitive constructs. At last George was doing what he did best and, particularly following the New Mexico State move, in a setting that he truly enjoyed. It brought him a great deal of personal satisfaction not only by virtue of its intrinsic merit but also because it earned him unequivocal acceptance into the basic research community. For all his earlier contributions, he had always felt that his work was considered tainted by the pure experimentalists to whom *application* was a dirty word. Whether this perception was accurate is arguable. But no one could (or did) challenge the scientific credibility of his CRT work.

The issues addressed and contributions made in these 14 papers cannot be adequately captured here, because each requires considerable background and technical detail. Hence I will try merely to convey a sense of what was accomplished in the context of the times. Engineering psychology had (and has) a long-standing affinity for CRT as a dependent variable because of its sensitivity to a host of important system characteristics (design features, task demands, and organismic and environmental variables). Moreover, CRT was at various times considered a way of indexing-if not actually modeling-human information processing functions, particularly with the help of the ubiquitous (and empirically robust) information-theory metric (H) favored by the applied community.

By the late 1960s, however, serious challenges had diminished the theoretical stature of information theory, and the now familiar multicomponent, structural models of human cognition were beginning to emerge from the basic literature of experimental psychology. Sternberg (as well as Ulric Neisser, Edward Smith, Michael Posner, and many others) saw the RT paradigm, properly modified to overcome its classical deficiencies and stripped of unnecessary information-theory baggage, as useful for validating components of the new cognitive models. *A* key development toward this end was Sternberg's binary classification task (BCT) and the associated logic of the additive-factors method (AFM). BCT overcame a weakness in classical RT methodology by permitting manipulation of variables aimed at specific model components (like "stimulus encoding" or "response selection") within a single task framework. AFM, on the other hand, enabled one to estimate, after collecting the RT data, whether the manipulations had affected the same or different components. Thus by systematically manipulating variables hypothesized that affect common (or different) processing structures one could progressively define and refine the entire cognitive architecture-at least in theory and with certain controversial assumptions.

George's research built on this foundation, extending it in several noteworthy ways. As cogently summarized by Dave Martin (1975) and explained in depth by Sam Mudd (1983), one way was an important

task innovation-use of random figures rather than familiar letters and numbers as stimuli-which had profound theoretical implications and led to resolution of a critical issue regarding the shape of the CRT-memory load function. Another, and perhaps the most far-reaching way, was the reinstatement of the much-maligned information metric as a valid index of central processing load (He). In a long series of studies involving manipulation of six different kinds of variables that converged on this construct, he was able to predict RTs with considerable precision.

Most of his other contributions to this general literature were specific refinements of the linear-stage model that permitted increasingly precise RT estimates for the BCT. Then as now, some engineering psychologists questioned the practical relevance of this entire line of work, while some cognitive psychologists faulted its explanatory value. The same could be said for almost any slice of our science, particularly when viewed in retrospect from the safe distance of nearly three decades. Neither science nor the applications derived from it progress in clearly delineated paths. Thus it is always difficult to evaluate how much a particular research program advanced either basic knowledge or the practice of human factors. But of one thing we can be certain: Progress toward understanding this facet of human performance as conceptualized at the time was accelerated considerably by the insight, the coherent approach, and the dogged determination that George Briggs brought to it.

For all the sharp turns in his research career, George never lost contact with either the applications or basic-science side of the engineering psychology house. Thus he could move easily from one to the other without compromising either set of values. His secret was that he understood both domains more thoroughly than did most of the natives and, more important, he saw the criticality of the relationship between them. Rigor without relevance is wasted effort; relevance without rigor is worse in that it provides false answers. He believed that, practiced it, and taught it to his students. I firmly believe that even in his most "basic" pursuits (the BCT work) he saw the potential for a vast array of systems applications somewhere down the road.

It was undoubtedly in part because of his ability to contribute importantly along the entire basic-applied continuum that he was called upon so frequently to serve the profession in a variety of capacities. For example, he was a member of the editorial boards of both the *Journal of Experimental* and *Applied Psychology,* as well as the *Psychological Bulletin* and *Organizational Behavior and Human Performance.* He edited *Memory and Cognition* from 1971 until his death. He also served with distinction on a number of national committees, including the NRC Advisory Board on Military Personnel Supplies and the U.S. Public Health Service's Study Section on Safety and Occupational Health. He was honored for his many contributions to the field with Division 21's Franklin V. Taylor Award. In a fitting, if premature, climax to an illustrious career, he was elected president of Division 21in 1974.

Perhaps his greatest legacy of all to the field was fashioned through his profound impact on students. Scores of young scholars, many of whom went on to play significant roles in the evolution of the field, were permanently affected by the experience of studying and working with him. It is no accident that the division's annual award for the best dissertation in engineering and applied experimental psychology bears the name of George E. Briggs. Today's winners and those of tomorrow cannot hope to appreciate the full significance of that name. What it says is that they are following in some mighty big footsteps along a path that has no shortcuts. But if they persist and maintain the basic values, they, too, can make a difference--even if the path comes to an untimely end.

References

Bahrick, H. P., Fitts, P. M., & Briggs, G. E. (1957). Learning curves-facts or artifacts? *Psychological Bulletin, 54,* 256-268.

Bilodeau, E. A & Bilodeau, I. McD. (Eds). (1969). *Principles of skill acquisition.* New York: Academic Press.

Martin, D. (1975). An untiring laborer: Major works in choice reaction time. Pent 3 of *A tribute to George: Reflections from colleagues.* Presented to the annual meeting of Division 21, Society of Engineering Psychologists, Chicago. Melton, A W. (Ed.). (1964). *Categories of human learning.* New York: Academic Press.

Melton, A W., & Briggs, G. E. (1960). Engineering psychology. *Annual Review of Psychology,* 11,71-98.

Mudd, S. (1983). *Briggs' information-processing model of the binary classification task.* Hillsdale, N.J.: Erlbaum.

Jerome Hirsch Ely, 1924-1963

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Jerome Hirsch Gerry) Ely was born in 1924 in Dallas, Texas, and died too young in 1963 in Stamford, Connecticut, when he was 39. His short but distinguished professional career was spent almost entirely at Dunlap and Associates, Inc. To that consulting organization he brought a strong interest in psychological experimentation, which stimulated the establishment of an in-house research laboratory, and a commit- ment to the solution of applied problems, which resulted in many important applications of human factors research findings to real systems.

Beyond these interests was his innate love for teaching, which found expression not only in his patient tutoring of colleagues but also in his instigation of an annual Human Engineering Institute, a week-long course for representatives of industrial and government organizations. His teaching skills found additional outlets in talks and symposia at the American Psychological Association and other professional groups, as well as in his role as lecturer at various universities. The esteem of his colleagues is reflected in the Human Factors Society (now the Human Factors and Ergonomics Society) annual award established in his name for the outstanding paper published in each volume of *Human Factors.* In his brief career Jerry Ely left his mark on the field in many different ways.

Jerry received his B.A. degree in psychology and mathematics at Southern Methodist University. His college years were interrupted in 1943 by a four-year stint in military service. As a captain in the Army Air Forces, European Theater he served as communications and cryptographic security officer. Returning to SMU, he graduated in 1947 and entered Purdue University for his M.S. and Ph.D. degrees in psychology. At Purdue he served as a part-time teaching assistant in 1948 and 1949, and as a full-time instructor in 1949 and 1950.

Jerry's interest in human factors applications became evident in the topic he selected for his master's thesis: "A Study of Accidents in a Shoe Company." In that study, his purpose was to determine the distribution of accidents among employees and identify relationships between accidents and personnel characteristics, taken from personnel records. Consistent with other findings in the field of accident research, he found a J-shaped distribution; a few employees had many accidents, and a large proportion had none. He found some evidence that employees with high accident rates tended to be younger, less educated, and more recently hired. Jerry's major advisor on this study was C. H. (Chuck) Lawshe.

His doctoral dissertation demonstrated Jerry's breadth of interest; he conducted "An Empirical Investigation of the Effects of Various Methods of Item Analysis upon Test Reliability." Using a vocabulary test, he compared four different methods of item analysis against the criterion of split-half test reliability, also varying test length and criterion group size. His results showed that three of the methods (D-values, Davis's modification of Flanagan's r, and Phi-coefficients) were equally reliable, and all were superior to the percent method. Longer tests were more reliable, but size of the criterion group had no effect.

Jerry joined Dunlap and Associates, Inc. in 1950 as a research associate. During the next 13 years, he rose steadily in the corporate ranks, ultimately becoming a vice president and director of the Human Factors Research Division. Also during this period he married Paula Cohen, and the couple had two remarkable daughters. Elissa, now a psychiatrist in the Boston area, divides her time between a medical career and writing sensitive newspaper columns that reflect on life and people and are published in the *Boston Globe.* Marcia produces television programs based on her interviews with the famous and not-so-famous, mostly movie and theatrical people. Jerry's warmth and his affection for people has clearly left a mark on his children.

Jerry's first assignment at Dunlap was on the so-called Project Therblig, a series of human factors studies on various systems in Navy ships and submarines under the direction of the late Ralph Channell. Project Therblig was one of the earliest military contract research programs in applied human factors. It was sponsored by the Office of Naval Research and implemented through the Navy's Special Devices Center (SDC), then at Sands Point, Long Island. (SDC later evolved into first the Naval Training Devices Center, then the Naval Training Equipment Center, and later the Naval Training Systems Center in Orlando, Florida. It is currently the Training Division of the Naval Air Warfare Center.)

Under Project Therblig, human factors design studies were conducted .on virtually every system and compartment aboard submarines: conning tower, fire control systems, torpedo room, propulsion

(engine control) station, periscope, diving control, and helm or steering station. The project was later expanded to include work on surface ships. These studies covered all aspects of man-machine system design, such as panel layouts, control and display design, workplace arrangements, lighting, and operational procedures. For the most part, the reports and recommendations resulting from the program were classified at that time and therefore not available for general distribution or publication. However, Jerry made several notable contributions to Navy system design, two of which will be described here.

In traditional submarines, the depth and diving angle (pitch) of the boat were controlled by two operators standing side by side at an extremely cumbersome workstation along a side bulkhead. One operator controlled the bow (or front) diving planes, and the other the stem (or rear) planes, each using a large, vertically mounted wheel that controlled the direction and rate of change of the plane movements. The boat responded to the plane settings by changing its pitch or angle, which in turn affected the rate of change of depth and eventually the depth. The responses were slow, and information about boat angle was displayed to each operator on a primitive "bubble" indicator, very much like a carpenter's calibrated level. Overshooting or undershooting the ordered depth was a common error, and continual corrections were required.

Jerry, together with Charles (Chuck) Kelley, had been experimenting with new tracking system concepts such as quickening, that is, displaying *to* the operator where to position a control in order to achieve a desired system output. The idea of quickening had originated with Frank Taylor and his colleaglies at the Naval Research Laboratory. Ely and Kelley were working with various concepts of computer-aided control to simplify operator responses as well as with predictor displays, which show the operator some aspect of the system's future state if no change is made in the control setting.

The research by Ely and Kelley had been aimed at employing these concepts during the training of tracking operators. But when the Navy began *to* design faster nuclear-powered submarines and was considering the idea of single-operator control of both steering and diving, Jerry and Chuck were ready with some radically new design concepts. The diving station could be rotated 90 degrees *to* face forward and, combined with the steering station, allowed one operator to control depth and course with a combined stick-and-wheel control, like an airplane pilot's control stick, if the control tasks themselves could be simplified. This could be done by applying the concepts of quickening and aiding, so that the operator might simply set pointers at the desired depth, pitch angle, course, and yaw angle; the diving planes and rudder would be automatically controlled to bring the boat to the desired depth and course by maneuvering through the desired angles. "Flying" the submarine would improve the ability to control it and permit a reduction in crew size, always a significant factor in submarines. Kelley and Ely analyzed the submarine control system and human operator control functions and worked out several alternative designs.

The submarine community received this exciting new concept enthusiastically. It has formed the basis for submarine steering-and-diving control station design ever since. In actuality, submarines today have two identical such stations, side by side, facing forward. The quickening and aiding concepts were applied to both depth control and steering control. The design allows depth and course to be controlled by a single operator, but often a second operator is assigned to the second seat for training purposes. The system has been found especially valuable for maintaining periscope depth in rough seas.

In recognition of this creative application of human factors research, Jerry was invited, along with Jack Dunlap, to attend the ceremonies at the launching of the second nuclear-powered submarine, the *U.S.S. Seawolf,* at the Electric Boat Division of General Dynamics Corporation in Groton, Connecticut in July 1955.

In addition to providing an ingenious solution to an immediate problem, Jerry's work illustrated an important principle of workplace design. *Therbligs,* named (backward) after the industrial engineer Frank Gilbreth and his Wife, Lillian, are standardized units of manual work activity such as *select, grasp,* and *transport,* normally used in factory assembly jobs. The Gilbreths, together with Frederick Taylor, the advocate of "scientific management/' employed an :irldustrial engineering approach to workplace efficiency. They attempted to reorganize the tasks and the working area so that fewer, shorter, and more productive motions (or therbligs) were used to perform a task. Jerry's work showed, first that this approach was not adequate to handle tasks that included a large amount of cognitive or judgmental activity and, second, that significant performance improvements could be achieved by introducing new concepts such as computer aiding, which made the task itself radically different. These areas, of course, are now so much a part of the human factors culture that they are taken for granted. But only a handful of pioneering spirits were thinking along these lines at that time.

A third significant principle was also illustrated by Jerry's work: the importance of carrying out a continual program of experimental research to produce knowledge that may not be immediately useful but

would be ready to apply on the appropriate occasion. Although this principle underlies our national science policy as well as that of our military services, it was (and still is) rare to find the policy at work within a profit-making consulting organization such as Dunlap and Associates. Jerry's work played a major role in shaping that company's next decade.

Another of Jerry's contributions to Navy system design was in the area of target detection and interception. In those days an important part of a naval task force consisted of radar picket ships, stationed around the perimeter of the task force, whose function it was to provide early detection of in-coming aircraft threats and control interceptor aircraft to meet those threats. The Navy was exploring the use of submarines as picket ships because they could proceed to and retire from picket stations with less chance of being detected than surface ships. Again under Ralph Channell's direction, Jerry led a team tasked with making a human engineering appraisal of the air control center in picket submarines. In addition to analyzing communications, evaluating delays in controlling interceptor aircraft, and recommending procedures for reducing delays, Jerry and his group were able to show that by using two operators rather than one for radar detection, the probability of target detection could be increased significantly, provided the operators were looking at different scopes. Thus, by refusing to stick with the narrow question originally posed, but rather asking how the total system's performance could be improved, Jerry was able to recommend a reallocation of functions that could make a significant difference.

Jerry also made major contributions to another major project, the first edition of the *Human Engineering Guide to Equipment Design,* edited by Clifford Morgan, Jesse Cook, Al Chapanis, and Max Lund. Sponsored by a joint Army-Navy-Air Force steering committee, and published by McGraw-Hill in 1963 after almost 10 years of preparation, the *Guide* was an early effort to provide designers of military (and other) equipment with human engineering data and general design recommendations for maximizing efficiency of human operation and use. Under contract to the AeroMedical Laboratory at Wright-Patterson Air Force Base, Dunlap and Associates was given responsibility for preparing four chapters of the book. So many people contributed to the contents of every chapter in the book, as writers, reviewers, editors, and section writers, that it is difficult at this late date to make attributions with any certainty. What is certain is that Jerry, working under the supervision of Jesse Orlansky, was a coauthor of three of the chapters. "Man-Machine Dynamics" by Ely, Hugh Bowen, and Orlansky, with a section by Al

Chapanis, described manual tracking systems, human and machine dynamics, control-display relationships, and the use of aiding and quickening to improve human control of complex systems. "Design of Controls" by Ely, Bob Thomson, and Orlansky, described various types of controls, their optimum locations, preferred movement relationships with display movements, shape coding, and optimum design features for both hand- and foot-operated controls. "Layout of Workplaces," also by Ely, Thomson, and Orlansky, covered workplace dimensions as determined by visual areas and body measurements, grouping and layout of controls and displays, seat and panel design, and the positioning of controls and displays that are shared by two operators. This first edition was the standard reference in the field until publication of the revised edition edited by Hal Van Cott and Bob Kincaid in 1972.

In 1960 Jerry became involved in a study of human factors in nuclear power plant design that foreshadowed more recent interest in this area following the Three Mile Island accident. The General Electric Company, Ltd., of England was designing new nuclear power stations and contracted with Dunlap to study the problems facing personnel in control rooms of such stations and recommend ways of reducing these problems. A three-man team, led by Jerry, spent four weeks in England observing operations and interviewing personnel. They quickly identified problems involving vigilance, equipment design, and training and prepared a report covering various aspects of design and operating procedures. Among their recommendations was that the control rooms be designed not as huge cathedral-type spaces but as smaller rooms more like ship bridges, so personnel had a stronger sense of being in control. They suggested that personnel work assignments be diversified and rotated to break up the monotony that might be induced by long unrelieved periods of instrument panel monitoring and that workstations should be designed so people could either sit or stand, giving them an opportunity to change their posture from time to time. The team showed how dials could be designed so that when operating conditions were normal all pointers would be aligned, and when any dial reflected ail abnormal situation it could be rapidly spotted as out of alignment. They also recommended the use of computers, not only for the relatively conventional function of setting off alarms in emergencies but also for more advanced uses such as simulating various types of malfunctions for training purposes. Finally, the group recommended that the control room never be left in the hands of a single operator, but that at least two people be on duty at all times. The study and findings were briefed to the Electricity Generating Board, the Atomic Authority,

and the Admiralty, among others; they were well received by G.E.C., Ltd., and widely publicized in the British press.

Despite his heavy schedule at Dunlap, Jerry's sustained interest in teaching motivated him to undertake lecturing and instructing activities at various universities in the New York-Connecticut area. During the academic year 1952 and 1953, he lectured at the City College of New York, teaching courses in general and industrial psychology. From 1953 to 1956, he was a visiting lecturer at Columbia University, teaching a graduate course in human engineering in the industrial engineering department. In 1957 he received an adjunct appointment as full professor at New York University to teach a graduate course in human engineering. This course, which Jerry was given complete freedom to organize, covered systems considerations, workplace layout, display design, control design, and control systems (division of duties among people and machines, tracking tasks, and watch-keeping). During this period he also taught at the University of Connecticut.

Jerry also found time to give talks and organize seminars for many professional and business groups. Among these were the American Management Association, the American Society of Mechanical Engineers, the Institute of Radio Engineers, the Flight Safety Foundation, the Army Chemical Corps Engineering Command, the Kiwanis Club, and the Design Research Conference, a group of industrial designers.

Although most of the human engineering activity in those days was centered on military and other large, equipment-based systems, Jerry was offered, and accepted, an opportunity in 1962 to speak before a Peace Research Institute-U.S. Arms Control and Disarmament Conference in New York City. His intriguing message to that group was that the complex issue of international arms control might be thought of as a systems problem in which disarmament actions were both inputs and outputs, somewhat analogous to a feedback loop. Thus, small unilateral disarmament steps might have important effects later on, resulting in larger output steps. Recent unilateral arms reduction initiatives by the United States, and subsequent responses by Russia, bear testimony to the soundness of Jerry's position. In his view, the role of social scientists in disarmament activities was not to be decision-makers but rather investigators of system goals and needs and then members of advisory teams charged with forecasting the consequences of alternative actions.

Jerry was an active participant in many APA conventions, most of his talks and symposia occurring before the formation of Division 21. He was one of the first to reflect the interests of engineering psychology in the :industrial and organizational setting of Division 14. As an example of his advanced and thought-provoking approach, he organized a Division 21 symposium :in 1961 dealing with the contributions of clinical and social psychology :in the design of human-machine systems. The symposium focused on the effects of human :interactions on the design of systems, a topic that even today is probably not receiving the attention it deserves. Thus, :in addition to playing a major role :in spreading awareness of engineering psychology among managerial and engineering personnel who had little :in any exposure to psychology, Jerry continually pushed psychologists beyond the limits of conventional thinking in their own field.

In view of Jerry's strong :interest :in teaching, it is not surprising that he conceived the idea of a Human Engineering Institute, a five-day training course for representatives of :industry and government. He organized and conducted the first such :institute at Dunlap and Associates :in 1953, with other members of the staff assisting as faculty. Combining lectures, laboratory sessions, demonstrations, and round-table discussions, it provided an opportunity for engineers, psychologists, and designers to learn about the latest human factors research findings, analytical and experimental methods, and design principles; to analyze design problems of :interest to themselves or their organizations; to test hypotheses; and to share approaches and solutions with their col- leagues. The course content was quite broad, covering anthropometric data and how to use them, perceptual processes, design of instruments, human motor responses, design of controls, control-display relation- ships, the working environment, research methodology, systems re- search :in human engineering, and :industrial applications.

It was one of the earliest, if not the first, such course to be offered anywhere, and it became an annual event at Dunlap, with the curriculum expanding to cover such topics as cognition, decision making, and computer aiding. Moreover, the format became the model for a series of similar institutes presented by Dunlap at various Army labs and centers around the country, as well as for personnel at Navy bureaus and labs :in Washington and San Diego. In all cases the courses not only presented human factors design approaches and principles, but also provided opportunities for attendees to develop approaches and often solutions to design problems they brought with them. It is not an exaggeration to say that Jerry's pioneer efforts contributed significantly to the spreading awareness of and interest in human engineering during this critical period :in the history of our discipline.

Jerry was always convinced of the need for laboratory facilities more sophisticated than the home-grown Heathkit he started with if Dunlap

were to offer clients a full spectrum of services. Obtaining corporate funds for equipment purchases was not easy but Jerry was persuasive, and over a period of time the company acquired an array of computers, displays, controls, and performance measuring devices. When Dunlap became large enough to move :into its own building :in Darien, Connecticut, :in 1961, the equipment assemblage was impressive enough to justify the allocation of a large area devoted to a formally designated laboratory. Jerry's lab soon became a thriving enterprise, and Dunlap expanded its activities :in experimental research.

This essay is supposed to concentrate on the professional rather than the personal achievements of its subject. But often it is impossible to separate the two. Jerry's nature and personal dealings were important factors :in motivating the personnel he supervised, which :in turn contributed to the professional achievements of the group. I would like to give just one example of the way his warm concern for the well-being of his staff led him to admirable heights as a motivational force.

The year 1961 was an unusually stressful one for his division at Dunlap and Associates, marked by many changes :in work assignments and several contracts requiring long periods of travel away from home. During the Christmas and New Year's holiday weeks Jerry himself was to be away from the office. Before he left he took the trouble to write a personal letter to every member of his group, secretarial as well as professional, recalling and praising that :individual's particular sacrifices and contributions to the preceding year's activities and expressing his wishes for a happy year to come.

I can think of no better way to summarize Jerome Ely, the man and his accomplishments, than by quoting the words on a memorial plaque that was placed on the wall of the laboratory he founded and directed:

> Jerome H. Ely, 1924-1963
> Scholar, scientist, teacher and
> gentle man. This laboratory is
> one of his many contributions
> to the profession of psychology and
> to Dunlap and Associates, Inc.