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A Milestone of Aeromedical Research Contributions to Civil Aviation Safety: The 1000th Report in the CARI/OAM Series

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16. Abstract

A historical, largely photographic retrospective is presented in recognition of the 1000th published report emanating from the FAA aeromedical research center officially established as the Civil Aeromedical Research Institute (CARI) in August 1960. The publications include 57 CARI reports (1961-1963), 1 CARI technical publication (1963), and 942 reports (1964-present) under the aegis of the (now) Office of Aerospace Medicine (OAM). The retrospective includes an historical section on the early development of civil aeromedical research. Additional, theme-related sections provide an indication of some of the varied research contributions and safety achievements of the Institute and cite some of the many individuals who contributed to the Institute's accomplishments.

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Finally, we acknowledge the dedication and accomplishments across the decades of the CARI/CAMI research teams…not all of them happen to be specifically cited herein…but all have promoted aviation safety for nearly half a century.

Further Information

All CARI/OAM reports may be accessed on the Internet at the following address:

http://www.faa.gov/library/reports/medical/oamtechreports/

A cumulative index of reports (by author, title, and subject) is published periodically as part of the OAM series. The most recent index, as of this date, is OAM report number DOT/FAA/AAM-05-1 (2005).

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Preface

A Milestone of Aeromedical Research Contributions to Civil Aviation Safety: *The 1000th Report in the CARI/OAM Series*

This is report #1000 in a series that began with the establishment of the (then) Civil Aeromedical Research Institute (CARI). It is a celebration of the (now) Office of Aerospace Medicine and its Civil Aerospace Medical Institute (CAMI) in its 45th year – its dedicated personnel, its research accomplishments, and its contributions to the Federal Aviation Administration's (FAA) safety mission. Like the other main components of the Institute – aerospace medical certification, education, and occupational health – the aerospace human factors and medical research divisions focus on the safety, health, and performance of the human element in the civil aviation system. That includes civil pilots of all types – private, airline, and other commercial – aircraft passengers, air traffic controllers, other FAA employees, and designated non-agency support personnel (e.g., aviation medical examiners). And the research includes assessments not just of human performance, but also of the personal and environmental conditions under which aviation-related work or outcomes occur so that unsafe outcomes can be avoided and desirable performance enhanced.

The incorporation of research on the human element within the Office of Aerospace Medicine (OAM) provides a venue that assures the FAA of a capability that will maintain a broad human focus. Within OAM, that focus is not territorially narrowed to the support of mainly internal medical issues but is broadened so that the agency has a resource to deal with the additional complex issues of how individuals and groups of humans perform and interact with equipment, environments, organizational structures, and other people, and how those interactions can be improved to enhance aviation safety and optimal performance.

And for those research issues that most directly affect OAM, incorporation of the research capability in the Institute with the other major medical responsibilities of the FAA aeromedical program allows the most direct of interactions and ease of communication and data sharing. It also facilitates interactive support, e.g., occupational health (in addition to providing clinic services to thousands of Aeronautical Center employees), provides medical monitoring of the altitude chamber, physical examinations of subjects when required, medical support for any untoward event, and is a significant research presence on CAMI's Institutional Review Board; the aeromedical education staff operates both the altitude and the environmental chambers and utilizes research data and innovations in their safety presentations and educational brochures. That co-location also stimulates research for – and from – the various medical specialty interests in aeromedical certification – whose physicians are also available for research and clinical support – while providing a structure for the most immediate application of medical findings. And the in-house nature of the vast majority of the research assures a strong cadre of scientific staff and thereby fosters knowledge, currency, and "bench" insights. It also permits the very rapid addressing of new, urgent problems as they arise. The reports that emanate from this paradigm meet the purpose of science – to document publicly the methodology, data, and conclusions of research and thereby permit scrutiny, evaluation, and replication. That process is designed to assure the transfer of accurate knowledge.

The first section of this report is an historical narrative that outlines the major milestones in the pre-CARI/CAMI history of civil aeromedical research. The remaining sections are primarily a visual celebration of the Institute, highlighting some of its many areas of research contributions and achievements and showing some of the many people who contributed to its productivity. In that spirit, some important achievements may be somewhat summarily noted (where obvious or documented in CARI/OAM reports) whereas for other contributions, not otherwise so documented, more detail may be provided. Thus, the main thrust is not a definitive history of CARI/CAMI research, per se, but rather a loosely historical presentation of selected accomplishments and unique individuals whose dedication – and sometimes prescience – made important and useful contributions to the agency, to aviation safety, and to the scientific community.

And the sum total of those contributions, and their application, is not limited to the published, documented report findings. The contributions also live in thousands of additional scientific presentations, journal publications, consultations, analyses, memoranda, conferences, training sessions, lectures, and presentations to agency officials, professional aviation groups, and the public. It is all of those venues, in addition to support provided to the National Transportation Safety Board, to military and space programs, and to national and international organizations seeking to improve aviation safety, that comprise the Institute's scientific enterprise. ❑

Civil Aviation Medical Administrators
From the Department of Commerce to the Civil Aeronautics Administration to the Federal Aviation Administration

Medical Director
Louis H. Bauer, M.D.
Nov 1926 – Nov 1930

Image Not Available

Medical Director
Harold J. Cooper, M.D.
Nov 1930 – Dec 1931

Medical Director
Raymond F. Longacre, M.D.
Dec 1931 – Aug 1933

Image Not Available

Medical Director
Roy E. Whitehead, M.D.
Nov 1933 – Jul 1937

Image Not Available

Medical Director
Eldridge S. Adams, M.D.
Jul 1937 – Jul 1940

Medical Director
William R. Stovall, M.D.
Apr 1941 – Jan 1958

Civil Air Surgeon
James L. Goddard, M.D.
Aug 1959 – Sep 1962

Federal Air Surgeon
M.S. White, M.D.
Aug 1963 – Sep 1965

Federal Air Surgeon
Peter V. Siegel, M.D.
Sep 1965 – Sep 1974

Federal Air Surgeon
Homer L. Reighard, M.D.
Mar 1975 – Sep 1984

Federal Air Surgeon
Frank H. Austin, M.D.
Oct 1984 – Feb 1987

Federal Air Surgeon
Robert R. McMeekin, M.D.
Sep 1987 – Dec 1990

Federal Air Surgeon
Jon L. Jordan, M.D.
Sep 1991 – Jan 2006

Acting Medical Directors
Eldridge S. Adams, M.D.
Aug 1933 – Nov 1933

William R. Stovall, M.D.
Aug 1940 – Apr 1941

Acting Civil Air Surgeons
John E. Smith, M.D.
Feb 1958 – Jul 1959

Hilliard D. Estes, M.D.
Sep 1962 – Mar 1963

Homer L. Reighard, M.D.
Mar 1963 – Aug 1963

Acting Federal Air Surgeons
Homer L. Reighard, M.D.
Oct 1974 – Mar 1975

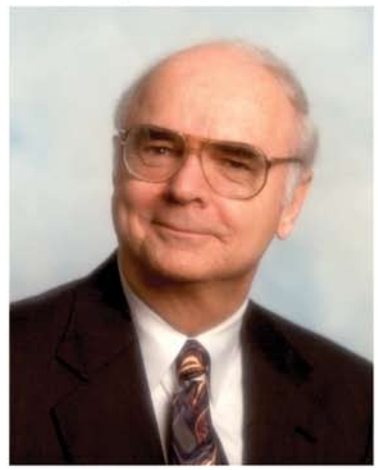
Jon L. Jordan, M.D.
Mar 1987 – Aug 1987
Jan 1991 – Aug 1991

CARI/CAMI Directors

Hilliard D. Estes, M.D.
Jul 1960-Apr 1961

Stanley R. Mohler, M.D.
Aug 1961-Dec 1965

J. Robert Dille, M.D.
Dec 1965-Dec 1987



William E. Collins, Ph.D.
Aug 1989-Jan 2001

Melchor J. Antuñano, M.D.
Jan 2001-Present

Acting Directors

George T. Hauty, Ph.D.
Apr-Aug 1961

Audie W. Davis, M.D.
Jun-Oct 1987
Mar-Apr 1988

William E. Collins, Ph.D.
Nov 1987-Feb 1988
May 1988-Aug 1989

Support Systems... Are People
...Some of the More Recent...

A Brief Early History of Aeromedical Research In the FAA

The beginnings of aeromedical research in what is now the Federal Aviation Administration (FAA) are sometimes associated with the creation of the Civil Aeromedical Research Institute (CARI - later CAMI) at the (Mike Monroney) Aeronautical Center in Oklahoma City. That association reflects in part the relatively sudden emergence and size of the enterprise at that time, including the construction of a unique edifice, designed by researchers from various scientific fields, and built specifically for aeromedical research across multiple specialties. Indeed, the creation of CARI did signal a marked change in the FAA's aeromedical research programs — significant increases in scope, funding, personnel, visibility, and responsibility. However, the aeromedical office of the FAA had a long, tortuous, and tenuous prior history of attempting to establish aeromedical research. That history, culled extensively from the work of Heber A. Holbrook (29), is summarized below. Underlying all of the sporadic early attempts to make civil aeromedical research a reality is the fact that aeromedical directors were faced with a variety of difficult medical, political, funding, and priority issues through the decades. Those various elements, not addressed here, are presented in detail by Holbrook (29) and Lopez (35).

Aeromedical Beginnings

In 1926, Louis H. Bauer, M.D., was appointed the first medical director of aeronautics within the Aeronautics Branch of the U.S. Department of Commerce. That appointment in the Air Regulations Division followed the enactment of the 1926 Air Commerce Act, which defined the U.S. government's responsibilities regarding civil aviation. Dr. Bauer was succeeded by Harold J. Cooper, M.D., in 1930, by Raymond F. Longacre, M.D. in 1931, and by Roy E. Whitehead, M.D., in 1933. It was during Dr. Whitehead's tenure that the Aeronautical Branch became the Bureau of Aeronautics (1934) in the Department of Commerce and government sponsored medical research began in civil aviation. That beginning took the form of a research project on oxygen deprivation at flight altitudes up to 22,000 feet in a simulator at the U.S. National Bureau of Standards (NBS), conducted jointly by Dr. Whitehead and NBS scientist James C. Edgerton (29).

The First Aeromedical Research Facility

In 1937, Eldridge S. Adams, M.D., succeeded Dr. Whitehead as medical director of aeronautics, serving until 1940. During his term, the Bureau of Commerce formed a new Safety and Planning Division (1937) that included research and development responsibilities and hired Wade Hampton Miller, M.D., as the government's first civil aviation medical research director — a position independent of Dr. Adams.

In 1938 the Medical Science Station – the first federal aviation medical research facility — began operation in Kansas City, Missouri with a main focus on Dr. Miller's specialty interest – airline pilot fatigue — as well as the effects of hypoxia and "more applicable" physical standards for all civilian pilots. The facility included a Link trainer, equipment to support simulated altitude studies, and medical examination equipment. Also in 1938, Dr. Miller negotiated the first federal aviation medical research contracts with Harvard University (the Harvard Fatigue Laboratory), Dartmouth University, and the University of Pennsylvania (29).

A Short Life

However, a confluence of political issues led to the closing of the Medical Science Station in mid 1940. Part of that confluence was the creation of an independent Civil Aeronautics Authority (CAA) by the 1938 Civil Aeronautics Act, which, among a variety of other changes, split medical responsibility into research and operations, with separate reporting heads. That circumstance lasted until 1940 when the CAA was placed back into the Department of Commerce as the Civil Aeronautics Administration (still CAA) with medical services combined under one Director – William R. Stovall, M.D., who replaced Dr. Adams and held the position for the next 17 years. The medical section (within the Certificate and Inspection Division of the Bureau of Safety Regulation) was nominally elevated in 1941 to the status of an aviation medical division, still, however, reporting to the director of safety regulation who reported to the CAA Administrator (29).

The Way It Was. Into the 1960s, prior to tricycle landing gears and the resulting higher aircraft profiles, eme rgency escape procedures were rudimentary. Some airlines used ropes and one carrier used a Jacob's ladder. The "telescape" pole (like a fireman's pole, but collapsible for storage) was another approach initially explored. The first escape slides were sheet-like and had to be held by those on the ground.

A New Research Start

In early 1941, the CAA Standardization Center – a training site for CAA field inspectors – opened in Houston, Texas. Seeing it as the potential site of a future CAA medical center, Dr. Stovall modeled a plan similar to the short-lived Medical Science Station in Kansas City and referred to it as the Houston Medical Center. Although the proposed medical facility seemed to gain favor with the CAA Administrator, the outbreak of WWII resulted in the conversion of the Standardization Center into a training facility for army ferry command pilots and precluded expansion of the medical concept (29).

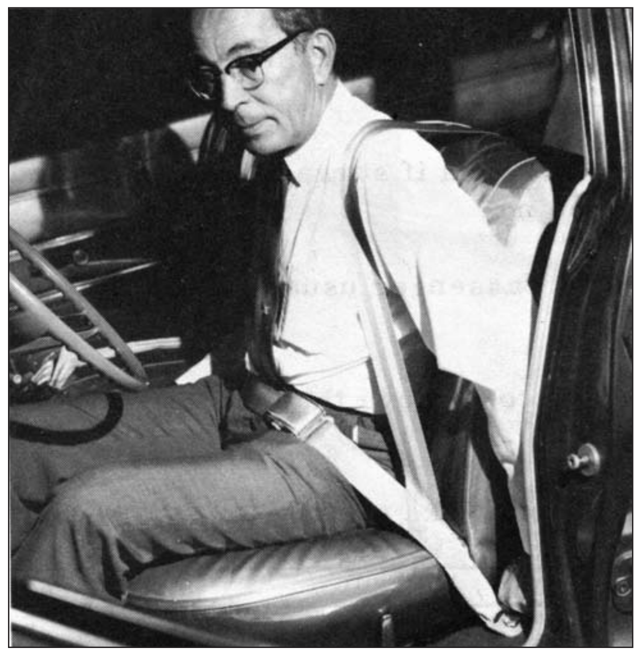
In early February 1943, Dr. Stovall submitted a postwar plan to the CAA Administrator that included an aeromedical research facility at the Standardization Center or, alternatively, on a university campus. In anticipation of postwar needs, the CAA reorganized in 1945 with the medical function in Washington renamed as the Aviation Medical Service (29). Then in 1946, the CAA Standardization Center was moved from Houston to Oklahoma City as the CAA Aeronautical Center.

While Holbrook (29) gives no rationale for the move (although he alludes to some later political fall-out), a 1949 Oklahoma City Chamber of Commerce publication (1) attributed the choice of location to the Aeronautical Center's "central geographic location in the United States which serves to reduce cost and time in the movement of CAA personnel and equipment, … the excellent year-round flying conditions here, and … the availability of suitable facilities which were formerly a part of the Army Air Base located on Will Rogers field"…A 1965 organizational survey of the Aeronautical Center included a history section that noted: "…The CAA Standardization Center at Houston was compelled to give up its facilities (caused by the returning National Guard) and the Administrator sought a central location at which to build a major civil aeronautical base. He decided upon Will Rogers Field at Oklahoma City, for reasons of good flying weather, aviation environment, and an enterprising offer by Oklahoma City officials to construct a modern physical plant to house such CAA organizations as would constitute the new CAA Aeronautical Center" (18). With respect to the latter, an FAA Historical Chronology item dated March 15, 1946, notes the move and concludes with "… Oklahoma City agreed to build an administrative building and two new hangers for CAA use" (47). Whatever the motivations, the CAA Administrator defined the Aeronautical Center as including an aviation medical research component among its six entities.

Thus, the "Aviation Medical Development Center" became part of the Aeronautical Center via CAA Administrative Order no. 57, August 2, 1946, but was unfunded and, in 1947 (until 1953), was renamed the Aviation Medical Branch (29). The branch was situated within the Aeronautical Center's Aviation Safety Standardization Division (18). Although a part of the Aeronautical Center, the medical research program received its guidance from CAA Headquarters where physiologist Barry G. King, Ph.D., had been designated (in 1947) as "Research Executive" for the Aviation Medical Service (29).

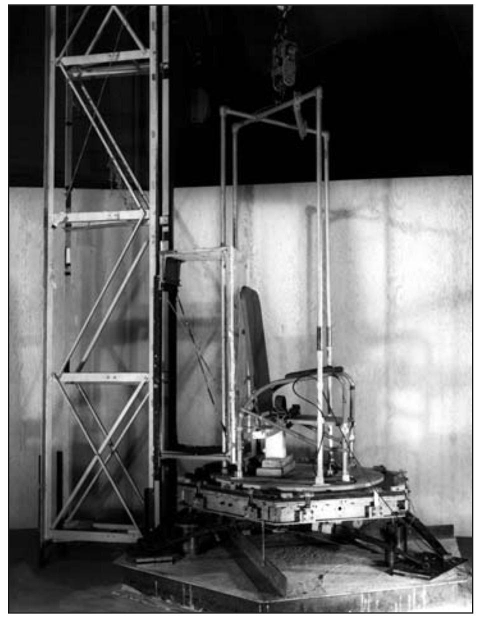
A Tentative Foothold

In October 1947, John J. Swearingen joined the Aviation Medical Branch as its senior scientist (29). Previously, in March 1947, Dr. Stovall had informed the CAA Director of Safety Regulation of the need to conduct scientific research on seats, safety belts, shoulder harnesses, and weight loads based on structural failures in several recent air carrier accidents. Swearingen, with prior U.S. Navy experience as a biomedical human factors scientist, was brought on board to conduct this type of research. However, research funding was a continuing



Early Impact. Swearingen in early tests of seat belts and seat harnesses and their capability to protect during crashes.

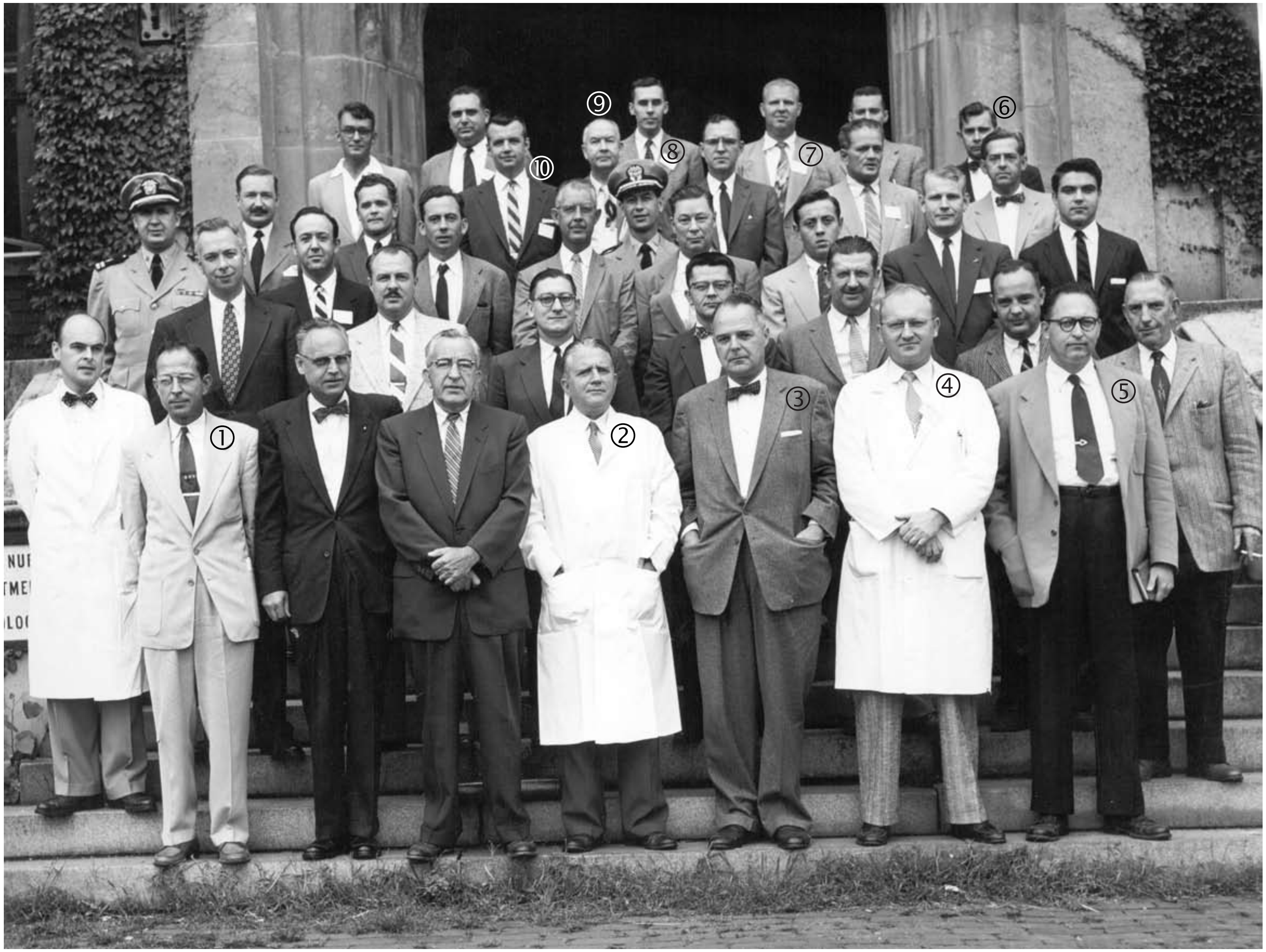
problem (both secretarial and administrative support were obtained from other Aeronautical Center branches) (28) and, although they were able to convert a former Army barracks building to an "Aeromedical Laboratory Altitude Chamber" (17), the ingenuity of the small team was regularly tested (allowing them to demonstrate skills that remained apparent in subsequent years) in their effective "make-do" solutions to research approaches. While the Aviation Medical Branch was defined as a research function, Swearingen established, within the small (2- or 3-person) branch, a laboratory as, at least nominally, a separate entity. As early as 1948, in a joint publication with Dr. King in the Journal of Aviation Medicine (31), Swearingen's affiliation was listed as the "Civil Aviation Medical Research Laboratories" (CAMRL). While he used this title quite regularly (at least once varying "Laboratory" with "Laboratories" [37]) to identify his organization in the text of formal reports (e.g., 53, 54, 55), the covers of those CAA reports regularly cited the origin of the work as the "Civil Aeronautics Medical Research Laboratory" at the Aeronautical Center in Oklahoma City (see also 23), despite the fact that the official organizational title "Aviation Medical Branch" was, according to Holbrook



Drop Tower. Swearingen used this vertical deceleration device (located in the Ohio State University football stadium) to test the effects of vertical impacts on spinal compression (assessed by spinal cord x-rays). Swearingen used himself as a subject for some of these tests as well as for wind blast tests and rapid decompressions.

You could learn a lot from a ...

A significant early Swearingen contribution was the development and use of articulated, anthropomorphic and (later) instrumented dummies – his were the first (Oscar (l) in 1949 and Elmer (r) in 1950) constructed for crash injury survival work. Both had joint articulation, calculated body and segment weight and centers of gravity, vertebral articulation, and some muscle resistance. Elmer also had a flexible torso and adjustable "muscle" tension in the spine. The dummies were used in hundreds of tests at CAMRL, Beech Aircraft, and the Air Force, and by the Atomic Energy Commission in A-bomb testing. Elmer can be considered the progenitor of modern anthropomorphic dummies.



(1) John J. Swearingen, CAMRL, (2) Richard L. Meiling, M.D., Associate Dean of the College of Medicine, Director of Research and Education, Ohio State University, (3) Barry G. King, Ph.D., Research Executive, CAA Aviation Medical Service, (4) Earl T. Carter, M.D., OSU aviation medicine residency program, (5) William R. Stovall, M.D., CAA Aviation Medical Director, (6) J.D. Garner, CAMRL, (7) Ernest B. McFadden, CAMRL, (8) John G. Blethrow, CAMRL, (9) Kenneth E. Dowd, M.D., immediate past-president, Aero Medical Association, (10) Harry W. Orlady, Captain, United Airlines (first chairman of the medical committee of the Air Line Pilots Association).

Ohio State University: Annual Postgraduate Course in Aviation Medicine, 1956 (3, 7, 28, 40).

A Strong Start. Garner began his CAA research career in Washington, D.C. working with John Smith, M.D., then head of the CAA medical standards branch, on ballistocardiographic research. That research was continued when he moved to Ohio State University to join CAMRL but was soon followed by his involvement in other projects. A seated Garner recorded sitting area measurements reported by Jack Blethrow and is shown testing the adhesive properties of an early model oxygen mask.

(29), retained until 1953 and the Aeronautical Center's Beacon magazine (51) referred to the Aviation Medical Branch in its reporting of research activities.

In July 1953, the CAA moved the medical research function to Columbus, Ohio, where (although Holbrook (29) mistakenly refers to the name as the Civil Aeromedical Research Laboratory) it was formally designated as the Civil Aeronautics Medical Research Laboratory – CAMRL (5, 47). That designation appears to have been primarily a title change in the official organizational chart since, prior to 1953, as noted above, the covers of the Aeronautical Center research reports all had used the CAMRL designation.

In Ohio, CAMRL was affiliated with the Ohio State University Medical School as part of that university's established plan for a wider-ranging "Institute of Civil Aviation Medicine" — a development for which Benford (2) assigned a primary role to Dr. Stovall. The University's plan was to "conduct research and provide a program of aviation medical education and training for civilian physicians and research investigators as a long-term and continuing activity to develop the technical manpower essential for the adequate support of civil aviation." There, Holbrook (29) indicates, Swearingen, J.D. Garner, Ernest B. McFadden, and Peter J. Sutro established a program comprising five research areas (sudden decompression effects on passengers, emergency oxygen administration, emergency aircraft evacuation, cockpit visibility and collision avoidance, and pilot fatigue) and began a series of injury studies "which extending over the next two decades would continue to form the basis for aircraft seating configurations for emergency evacuations, exit and window size and design, and human tolerances to impact forces." However, federal funding was very limited — as it had been in Oklahoma City — and in June 1958, "prompted by political maneuvering," according to Holbrook (29), the CAA Administrator, James T. Pyle, moved CAMRL back to the Aeronautical Center in Oklahoma City (47). Lopez (35, an attorney in the Medical Standards Division) authored an aviation medicine history for the Civil Air Surgeon in 1959 and attributed the move (with some apparent dissatisfaction) to the efforts of Roy Keely, the CAA director of flight operations and airworthiness, who worked "incessantly" — and, if so, successfully — for the return of CAMRL to the Aeronautical Center.

Congress Provides a Foundation

Meanwhile, in 1956, legislation had been introduced in the Senate and the House to modify the Civil Aeronautics Act of 1938 to define "civil aviation medicine" (the "Civil Aviation Medical Act of 1956"). It was neither sponsored nor supported by the CAA — and failed. The bill, which would have created both an Office of Civil Aviation Medicine directed by a "Civil Air Surgeon" and a medical facility — a Civil Aeronautics Medical Institute (CAMI!) — was reintroduced the following year. Hearings were held by Oklahoma Senator Mike Monroney but the bill (the "Civil Aviation Medicine Bill") languished in committee. Shortly thereafter, Senator Monroney began work on the bill that was to become, in August 1958, the "Federal Aviation Act of 1958" — to create an independent federal agency. In the meantime, during January, Dr. Stovall had resigned for health reasons as CAA medical director; his deputy, John E. Smith, M.D., had been made acting medical director. The Federal Aviation Agency began operation on December 31, 1958 (29).

Only Temporary. Swearingen's relocated team occupied this large, former U.S. Navy gymnasium on the north campus of the University of Oklahoma until the CARI building opened. Similarly, other CARI recruits temporarily occupied adjacent barracks-type buildings.

CARI Takes Form

As part of the organizational changes that followed the FAA Act of 1958, an Office of the Civil Air Surgeon was established (to become the Bureau of Aviation Medicine, independent of the CAA, in 1960; the Aviation Medical Service in 1961; and the Office of Aviation Medicine in 1963). Dr. Smith served as acting Civil Air Surgeon until July 1959 when James L. Goddard, M.D., an officer in the Public Health Service, was appointed; Dr. Goddard named Dr. Smith as Chief of the Research Requirements Division (29).

On October 31, 1959, the FAA announced plans for a Civil Aeromedical Research Center to be established at the Aeronautical Center in Oklahoma City (5). Shortly thereafter, Robert T. Clark, Ph.D., a scientist from the U.S. Air Force (USAF) Aerospace Medical Center in San Antonio, Texas, was appointed by Dr. Goddard as the research chief and deputy director of the research function; by December, he was in Oklahoma City where he joined other early staff members of the nascent facility (30); they were initially housed on the second floor of Hangar 8 at the Aeronautical Center (9, 30).

Included in the new organization was the CAMRL contingent, that had relocated from Ohio to barracks buildings that had comprised the World War II Naval Air Technical Training Center in Norman, Oklahoma (21). Although Holbrook (29) indicates that here CAMRL took the title of "Aeromedical Research Institute (ARI)," it appears that the laboratory continued to be referred to as CAMRL (50) — or even as the Civil Aeronautic<u>al</u> (vs. Aeronautic<u>s</u>) Medical Research Laboratory (37) into early 1959, despite the change from CAA to FAA. Later, in a 1959 publication, McFadden, Swearingen, and Wheelwright (38) referred to their organization by the title Swearingen tended to use during his first stay at the Aeronautical Center — the Civil Aviation Medical Research Laboratory.

In November 1959, consistent with the FAA announcement a month earlier, the Aeronautical Center's Beacon publication (20) referred to the (short-lived title) Civil Aeromedical Research Center citing the same Aeronautical Center routing symbol (AC-266) as had been used previously in the Aeronautical Center's phone directories for September 1958 (9) and March 1959 (19) to designate either the "Civil Aeronautics Medical Research Lab" or Swearingen's preferred "Civil Aviation Medical Research Lab." By whatever prior name, Swearingen's protection and survival laboratory was the established core of the new Institute.

By February 1960, a group of researchers recruited from the USAF School of Aerospace Medicine had arrived (30); others soon followed. In May 1960, the growing group moved to Norman, Oklahoma, to the unoccupied World War II Navy buildings on the University of Oklahoma's North Campus (22, 30). A June 1, 1960 memorandum from FAA Administrator Elwood P. Quesada (48) to the Aeronautical Center authorized the negotiation for aeromedical space to comprise 133,000 sq. ft. split between two buildings (the smaller one, essentially the protection and survival laboratory, to be located near the flight line.) A subsequent memorandum from Administrator Quesada (49), dated July 28, 1960, changed the requirement to a single, larger building (146,000 sq. ft.).

Also in July, Hillard E. Estes, M.D., from the Lovelace Foundation, was appointed (and succeeded by Stanley R. Mohler, M.D., in August 1961) as director of the Oklahoma City medical facility, which had been renamed the Civil Aeromedical Research Institute — CARI. That change (from "Center" to "Institute") occurred no later than February 1960, based on references to CARI in a "projected growth at the Aeronautical Center" document (41) and in an Aeronautical Center Beacon magazine (21), both dated that February. The basis for the change was "to avoid confusion of two 'centers' at one location" (24). Despite all of this activity, remarkably, CARI was not formally created as an organization of the Bureau of Aviation Medicine until August 15, 1960, by Bureau of Aviation Medicine Order No. 60-2 (29).

Meanwhile, locations at the Aeronautical Center had been identified in 1959 for the new facility and design plans had been developed with primary input from the early research scientists. The size and major facilities of the building were approved by August 1960. However, the Airport Trust apparently constructed the building according to the plans submitted by the scientists. That approach resulted in a facility comprising 226,141 sq. ft. when completed (40, 45) instead of the 146,000 sq. ft. cited in Administrator Quesada's authorization letter. The move from the Norman barracks buildings to the Aeronautical Center was accomplished in October 1962 when the elegant new CARI building opened.

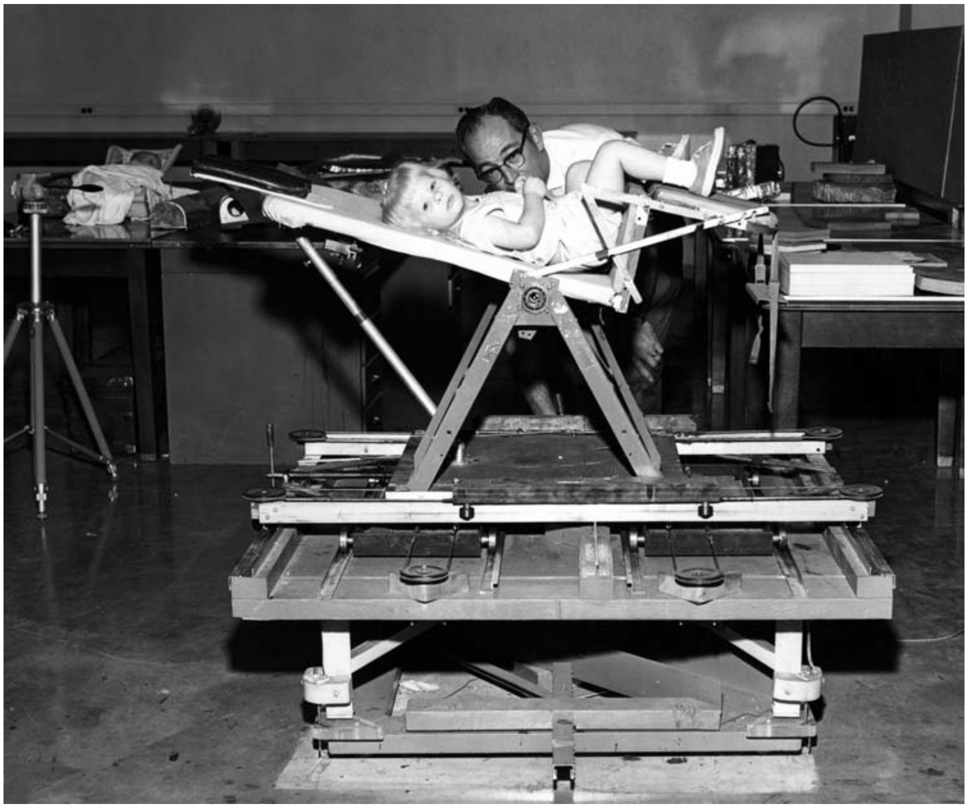
The speed and efficiency with which the CARI facility moved from concept to operation is attributable primarily to the fact that it was privately constructed — by the Oklahoma City Airport Trust. The Trust rented it to the FAA for a 25-year period, at the end of which time the cost of the building was totally paid; subsequent costs were for maintenance and improvements.

From CARI to CAMI

More detailed information regarding early developments within the Institute can be found in Holbrook (29)and in several historical vignettes published as an appendix to this report. For purposes of this brief history, it is necessary only to indicate that, in 1965, the Institute's organizational scope and structure were enlarged and, on October 1 of that year, it was renamed the Civil Aeromedical Institute — CAMI (29). The organizational changes resulted in all of the research laboratories that originally comprised CARI being designated as an aeromedical research branch along with aeromedical certification, aeromedical education, and a medical clinic branch that included national industrial hygiene responsibilities (17). In 1987, the aviation psychology laboratory acquired separate branch status (from the Aeromedical Research Branch) as the Human Resources Research Branch and became the Human Factors Research Division in 2002 (all of CAMI's branches were elevated to division status in 1998). In 2001, CAMI's mission was expanded to incorporate commercial space transportation and its name was changed (on May 24, 2001) to the Civil Aerospace Medical Institute (still CAMI by acronym) along with the change in function and name of its parent organization — from the Office of Aviation Medicine to the Office of Aerospace Medicine (25). ❑

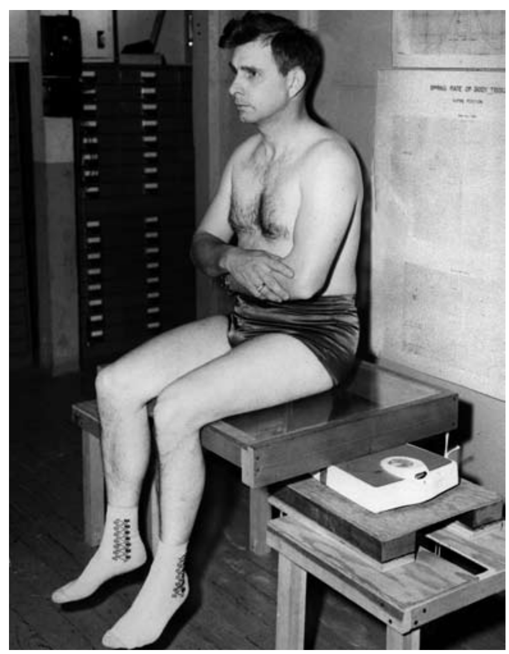
A World Class Facility. The CARI building (l) when it opened in 1962 and its setting in circa 1980 (r) after its renaming and other Aeronautical Center developments.

The Swearingen Legacy ... Continuity and Direct Applications



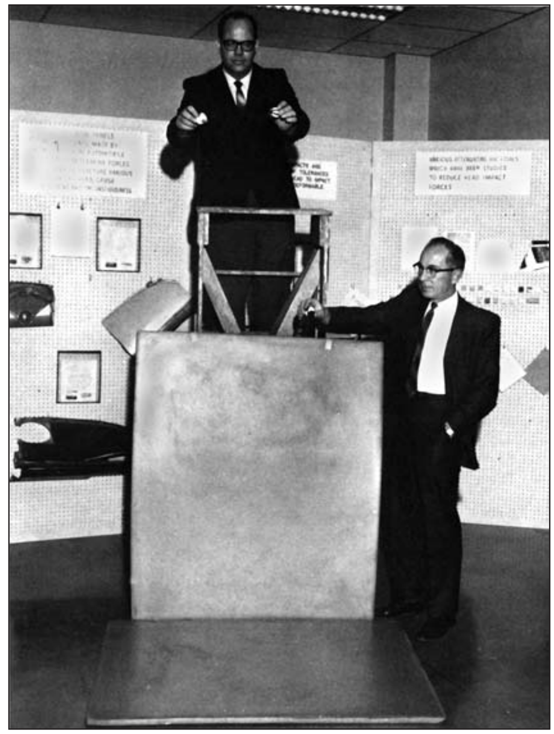
For the Least Able. John Swearingen, measuring the center of gravity for children.

While officially the second CARI report (the first in 1962), the study of sitting areas and pressures by John J. Swearingen et al. represented one aspect of a line of safety research that Swearingen had been conducting for 15 years with a small total staff of 1 to 4 associates (and an occasional collaborator) in his underfunded (and variously named) Civil Aeronautics Medical Research Laboratory. Some of that work from the late '40s to the late '50s was captured in a black-and-white motion picture film that was donated in year 2000 to the Smithsonian Air and Space Museum; a CD copy of the film is available from the CAMI library (52). The new CARI structure incorporating his protection and survival laboratory provided Swearingen with greater opportunities, funding, and support to pursue his research programs – a part of which came to be termed "cockpit delethalization." In addition to formally published reports, Swearingen, his team, and their successors conducted numerous unpublished studies at the request of agency representatives and safety groups. They interacted closely with industry and the agency to define safety shortcomings and support safety improvements.



Not Just for Comfort. Sitting pressures and areas on seats have an influence on seat design for safety, prevention of fatigue, and as a base for control movements.

Damage Control. Many of Swearingen's early tests used fuselages like this one to determine where (and what) protective materials might best be located.



Eggs-actly. This demonstration at a booth during a safety exposition in 1967 provided a directly observable indication of the importance of CAMI programs researching materials that would provide more protective surrounds in aircraft (and automobiles). Harry L. Gibbons, M.D., research branch chief, dropped fresh eggs from his position on the ladder, while Swearingen dropped an egg from shoulder height, onto a section of material that Swearingen was assessing in crash studies. The material cushioned the "blow" from the falling eggs so that none of them broke.

Early Impact Research

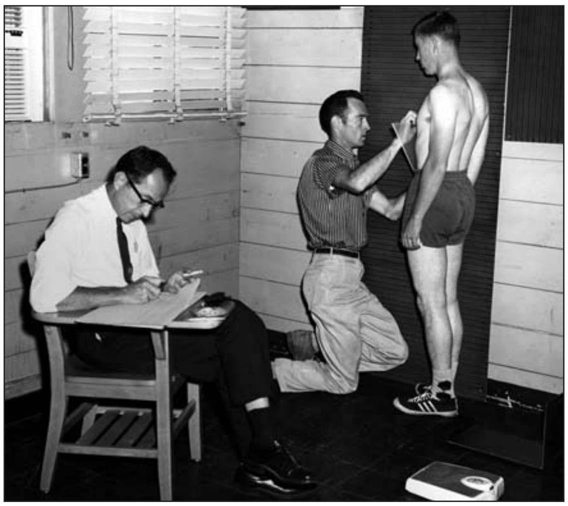
Swearingen's crash research tended to emphasize general aviation aircraft cockpits, although it included commercial cockpits and cabin interiors. That research was rooted in a program of accident investigation supplemented by the laboratory use of dashboards from crashed automobiles (in which the front seat passenger had been injured) and fuselage sections from crashed aircraft. Swearingen and his team subjected the dashboards to analyses based on the medical records of those injured in the accidents. He then secured undamaged dashboards from similar junked cars and worked at simulating the damage using instrumented dummy heads on a sled-catapult device he had constructed. Based on about 1,000 tests during a 3-year period, he determined the impact forces that could be tolerated by the head and face. He then sought force-absorbing materials and padding that could be used in the dashboards and fuselage sections to reduce injuries.

Swearingen extended the impact work using CAMI's 2-rail track to include the head and face injury potential of then-current airline seats. He also noted that some passenger injuries resulted because their seats came loose from the floor, a circumstance that was sometimes assisted by the forces applied when a seat was involuntarily kicked by the flailing legs of a passenger seated behind it.

The use of existing data regarding injury due to impacts was not limited to Swearingen's accident investigations. The laboratory's Richard G. Snyder, Ph.D., collected reports on a national basis about people who suffered significant free fall impacts (often from both successful and unsuccessful suicide attempts) and analyzed those reports for clues to survival. In addition, in collaboration with another CAMI anthropologist, Clyde C. Snow, Ph.D., Snyder conducted primate studies of impact injuries in pregnancy, from restraint system trauma, and from backward vs. forward facing vs. lateral body orientations with a lap belt restraint to develop criteria for protecting aircraft occupants. Those protection and survival studies were conducted during the mid-1960's at Holloman Air Force Base, using the U.S. Air Force's Daisy Decelerator. The Holloman AFB division chief in charge of the conduct of those tests was Richard F. Chandler (8). While that occasion was Chandler's first contact with CAMI, he would later join the Institute and subsequently succeed Swearingen.

Cutting a Wide Swath

From the start-up in the late 40s to the establishment of CARI, Swearingen successfully guided the tiny civil aeromedical research function through a trying period of more than a dozen years. That period involved two major (and one lesser) geographic moves and a consistent shortage of resources. Despite those difficulties, Swearingen and his small team successfully explored injury-reducing and life-saving solutions for general aviation and commercial aircraft. With the advent of CARI, he was able to build on that team and assembled and managed a skilled and productive staff dedicated to aviation safety research.



Measuring Success. Anthropometric measurements recorded by Swearingen were important elements in his efforts to protect aircraft occupants.

During those periods and until his retirement in 1972, Swearingen's own studies ranged from recording (and using) basic information on bodily centers of gravity at different life stages to exploring the effects of sudden decompressions on himself and on dummies situated next to various-sized windows (which led to his recommendation that windows be double-paned) in addition to his crash-injury investigations. He pioneered in studies of voluntary human tolerance to vertical impact, human strength requirements for operation of aircraft controls, and release mechanisms for emergency exits and doors, and in developing recommendations for reducing or preventing injuries from rapid decompressions. He designed a test device that allowed him to measure the range of motion for seated passengers wearing a safety belt, defined seat load distributions, developed maps of impact tolerance for the human face, and assessed the protective performance of instrument panels when they were subjected to crash loads. With collaborator Ernest B. McFadden, he developed and was awarded two patents (nos. 2,809,633, and 2,921,581) which described an adhesive oxygen mask and the drop-down mechanism to present the mask during decompression.

Successful Succession

When biologist Swearingen retired in 1972, he was succeeded by engineer Chandler who continued the established safety research thrusts as head of the protection and survival laboratory and brought to the research program his own special skills and perspectives. While Chandler is best known for impact-related work and the dynamic evaluation of aircraft seat and restraint systems, he, like his predecessor, involved himself in a variety of projects in other areas of research (e.g., the maximal control force capability of female pilots, issues related to the use of canes by blind passengers in aircraft cabins, and the development of appropriate dummies for impact testing). The protection and survival laboratory was in good hands. ❒

Explosive Decompression. An early study by Swearingen used Elmer – and a doll – to assess the effects of a rapid decompression from a blown-out window in an altitude chamber. Swearingen's recommendations related to window size, use of double panes, and an increased distance of the passenger from the window. In developing his recommendations, Swearingen exposed himself to a number of rapid decompressions.

CARI's First Report ... An Enduring Direction

The Beginning

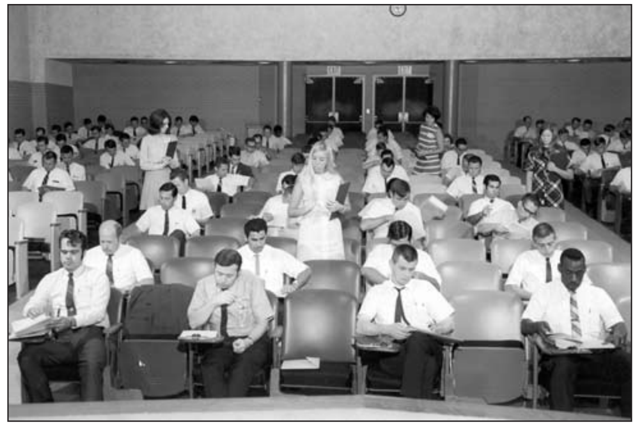
CARI's first report – the only one published in 1961 – involved close cooperation with the FAA Academy and its entrants into the air traffic control specialist (ATCS) training program. That report began the Institute's research programs, initiated by David K. Trites, Ph.D., on developing and validating tests for selecting ATCS trainees and on assessing Academy training and its measures as predictors of trainee success – an involvement that continues to date. Training–performance criteria for ATC students in the tower, center, and flight service options were also the subject of one of the first two CARI research contracts (the other was a vestibular investigation) with organizational elements of the University of Oklahoma; both contracts were completed in 1964 (6, 39).

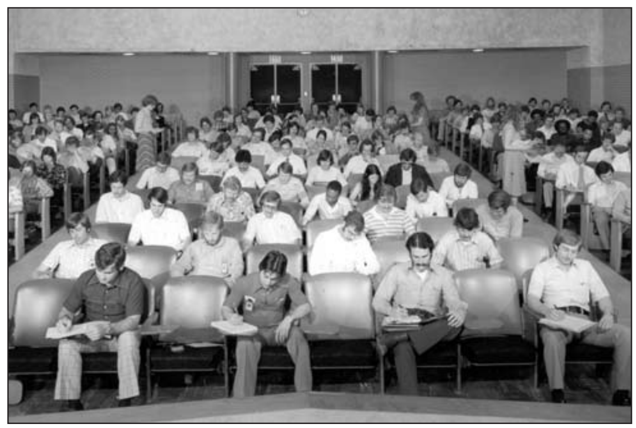
Note that CARI/CAMI tests comprised the official Office of Personnel Management selection battery (and later also included a CAMI-developed Occupational Knowledge Test). Passing that battery was required for eligibility to be considered for an ATC trainee slot; the ranking of successful candidates depended upon their test scores, education, and experience.

During most of the first two decades of CARI/CAMI's selection and training research, Bart B. Cobb was a driving force. He was frequently consulted by Washington Headquarters groups in the offices of air traffic and personnel for the information and special analyses of pertinent data that he provided by numerous letters and memoranda as well as his formal CARI/OAM reports.

In addition to developing new tests and scoring schema, effects of age, education, gender, prior experience,

First Hand. Bart Cobb (l) and CAMI director J. Robert. Dille, M.D., (r) during an air traffic control tower visit to directly observe ATC procedures.





Culture Changes. Recently-arrived FAA Academy students provided demographics and took CAMI tests of new items designed to improve future selection criteria. Cultural changes are evident in student make-up (top to bottom: ca. 1965, 1977, ca. 1983).

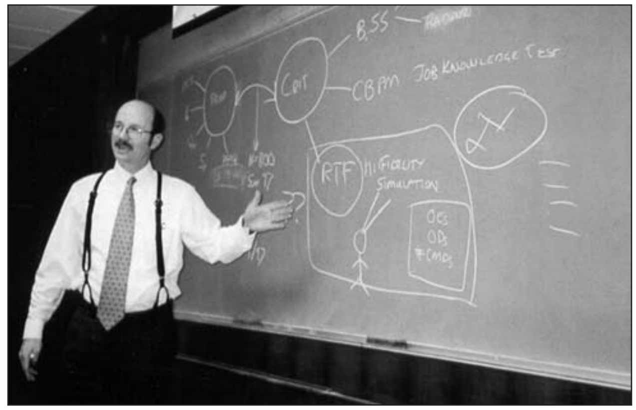
The Academy. Air traffic control classes in the 1960s (l) and the 1980s (r).

personality, potential test bias, and others have been researched through the years by Cobb and his psychologist successors – Drs. Mary A. Lewis, James O. Boone, Alan D. VanDeventer, Carol A. Manning, Pamela S. Della Rocco, Dana M. Broach, and Raymond King – a grouping that suggests the increased size of the air traffic controller programmatic research effort. The agency has been provided through the decades with criteria for the best candidates with the best chance to succeed and with updated selection and training criteria that are fair, reliable, valid, and cost effective. Updating refers not only to the advances in ATC systems that might change aptitudes and abilities required for success, but also to the delivery systems for assessing skills necessary for job performance and to the cultural changes that affect what applicants bring to the job. Included in that updating is another area that receives CAMI attention, primarily by David J. Schroeder, Ph.D., – viz., the assessment of varied approaches to defining personality-related elements as they relate to success in air traffic control work (including a continuation of the work of Roger C. Smith, Ph.D., on perceived stress and on "burnout").

The Academy's new RTF. Boone (top) during tests of "ghost pilot" demands for staffing the Academy's new Radar Training Facility (bottom).

Analysis. Manning reviewing air traffic student data for a briefing on the Academy program to Washington officials.

Documenting Outcomes. Della Rocco (l) provided analyses of Academy student outcomes to Dallas-Ft. Worth air traffic manager Joseph Kisicki and Britain's David Hopkin, an internationally noted expert on air traffic control work.



D.C. Discourse. Broach providing a briefing in Washington headquarters on conceptual relationships in air traffic controller selection.

The Academy

CAMI has also provided the FAA Academy with additional scientific support. Beginning in 1976, CAMI's relationship with the Academy became formalized in conjunction with a new pass/fail program. CAMI began to conduct analyses of various proposed selection and training scenarios and, at the request of the Academy, to brief visiting Washington officials as an "independent analyst" on statistical aspects of the air traffic program. And when support personnel were needed to operate the manual controller, remote, and three "ghost pilot" positions for each radar training sector of a new radar training facility constructed at the Aeronautical Center in 1980, Boone undertook studies to assess the training time and error rates of ATCS trainees, community persons, and physically handicapped persons. Results indicated that handicapped and community persons could perform effectively at the "ghost pilot" positions and recommendations that they be hired to do so were accepted. Another Boone study, conducted at the FAA Technical Center in Atlantic City, compared over-the-shoulder vs. computer-derived measures of student performance on the RTF and found better outcomes with the computer measures.

Maintaining State of the Art

With the aim of reducing the time required to establish trainee success or failure (several weeks of class work followed by simulated air traffic control in an Academy laboratory), a computerized pre-training screen (PTS) was developed. The PTS was used for about 3 years in the early '90s to hire 1800 trainees and reduced success/failure screening time from 9-12 weeks to five days. That screen was followed by development of the AT-SAT, a computerized aptitude test battery currently in use. The AT-SAT (Air Traffic Selection and Testing) battery was the product of a CAMI-Academy-Air Traffic collaboration with contractors and university experts; Della Rocco headed the CAMI effort that included participation in the validation of the battery with more than 1,000 en route field controllers. The AT-SAT replaces the written OPM test and provides a pre-training screen as well; testing/screening is accomplished in a single day. That improved efficiency (along with a retirement model prepared by Broach to identify future training requirements) will be significant in the plans and procedures being developed by the FAA to recruit and train a large, new group of controllers. The new group will be required to replace the controllers hired during the strike recovery period in the early 1980s, as the latter become eligible for retirement. Moreover, new technologies and procedures require constant re-evaluation of the defined knowledge, skills, and abilities for success in the air traffic controller occupation to assure safety in tomorrow's national air space system. Related recent work has been conducted on completing job-task analyses for airway facility specialists and for computer specialists in the air traffic service. ❑

AT-SAT At Last. Della Rocco and Manning displayed the first poster announcing the new test battery for air traffic controllers. Both were formally acknowledged for contributions toward success of the 4-year project with special recognition of Della Rocco by the AT-SAT Executive Steering Committee for her service as the scientific/technical representative, defining test validation requirements, and contributing to decision making on the scientific approach.

Aeromedical Certification ... and Health

The Priority Function

The top priority of the Office of Aerospace Medicine and of CAMI is not research but the recurrent aeromedical certification of all of the country's civilian pilots. However, the co-location of the research enterprise with the certification function encourages research from both entities. Some studies have described the performance effectiveness of aviation medical examiners; others defined disease prevalence and incidence among pilot populations; still others compared medical status variables among accident vs. nonaccident airmen.

From the certification staff, Charles F. Booze, Ph.D., was pre-eminent for more than two decades in tapping the extensive certification database and reporting his findings on a variety of certification topics. Similarly, beginning in the mid '70s, Shirley J. Dark initiated a series of studies on characteristics of medically disqualified airmen in general and air line pilots in particular.

Data, Data, Data. Charles Holmes in one of the many older racks of certification data files. A state-of-the-art electronic certification records system is now in place for immediate informational access.

Early Laboratory Research

Very early biodynamic studies by Bruno Balke, Ph.D., assessed work capacity, cardiorespiratory capacity, and physiological aging issues. That work led to research by Michael T. Lategola, Ph.D., on the early identification of coronary heart disease and physical fitness regimens that would help pilots who had experienced myocardial infarctions to restore their cardiovascular functioning so that they might regain their medical certificates. Other work by Lategola included the near term effects on psychomotor performance and physiological functions of physical exertion, of crash dieting, and of blood donations in conjunction with simulated altitude exposures.

Vision: A Major Research Issue

Studies from the research divisions have used certification data to develop profiles of pilots with regard to types of visual correction (contact lens use, aphakia,

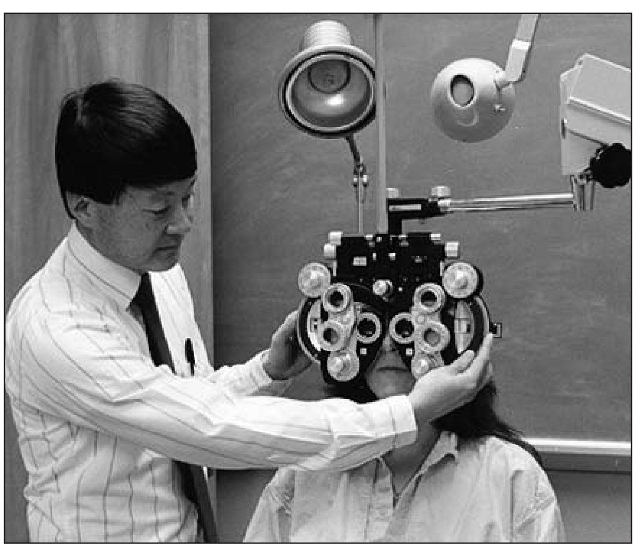
Medical Exchange. (upper) J. Robert Dille, M.D., CAMI director (l), a frequent research collaborator with Booze (seated), discussed certification data with two Russian Aeroflot visitors in 1978. A.W. Davis, M.D., (r) headed aeromedical certification. (lower) Shirley Dark explaining a new certification subsystem for medical data. Federal Air Surgeon Jon L. Jordan, M.D., is 2nd from left.

Basic Support. Balke's work capacity studies and Lategola's tilt-table tests supported certification goals.

radial keratotomy, radial keratectomy), and to develop tests, procedures, and data (e.g., on the x-chrom lens) to assist in aeromedical decision-making for pilots and air traffic controllers. These studies, conducted by Kenneth W. Welsh, O.D., and Van B. Nakagawara, O.D., have relevance to the fact that optimum vision is essential for pilots not just for detecting other airborne traffic and reading the instrument panel, but also for visual detection on the runway and taxiway and for reading maps and other printed material. Thus, Nakagawara has analyzed the influence on aviation safety of various types of refractive corrections and surgeries as well as assessing the influence of laser light exposure on pilots' vision and performance. In further support of the certification process, Henry W. Mertens, Ph.D., conducted studies validating clinical tests of color vision in predicting responses to practical tests, devising updated criteria for clinical assessments of color vision capability, and developing improved practical tests. Since the ability to distinguish colors has significance for both pilots and air traffic controllers, color vision is a component of their periodic medical examinations. Mertens' studies with Nelda T. Milburn, Ph.D., included validating cut-off scores on pseudoischromatic plate tests and other instruments, including the signal light gun, and the development of new practical tests for the air traffic controller occupation.

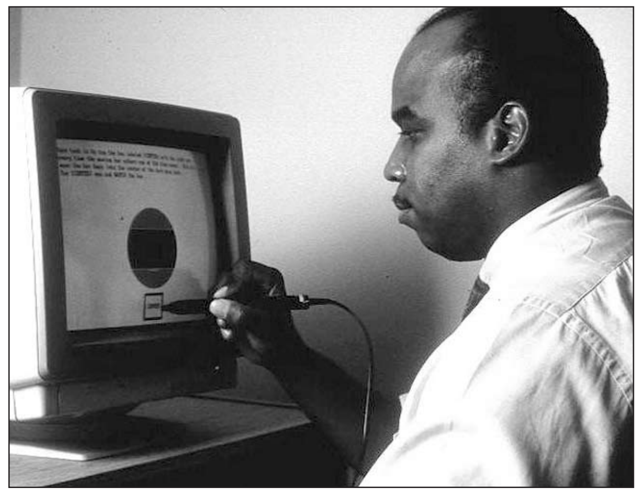
Noise and Hearing

Studies of the hearing profiles for aviation personnel and of cockpit and cabin noise exposures (to assess the risks of hearing loss based on exposure) were conducted by researcher Jerry V. Tobias, Ph.D., along with preventive guidelines and ratings of various types of ear protection. Cockpit noise intensities were determined in a variety of



Seeing It All. (above) Nakagawara checking visual acuity; (r) color vision testing for a study by Mertens.

Criterion Setting. (above) Nakagawara conducted retinal sensitivity tests under mild hypoxia in the altitude chamber. (r) Mertens used an air traffic control tower signal light gun in developing medical certification criteria for color vision tests.



Cogscreen. (r) The final touches being applied to the new cognitive test at CAMI.

Noise and Speech. Tobias measured speech intelligibility and noise-based hearing loss © 1970, The Oklahoma Publishing Company.

single and twin-engine aircraft to determine exposure-risk levels for hearing loss. And groups of aircrew personnel were tested to determine auditory profiles associated with their flight history. Recommendations for hearing conservation by use of earplugs were accompanied by tests and ratings of the effectiveness of a variety of ear protectors.

Head Trauma

During the '90s a government/academia contract team headed by Jerry R. Hordinsky, M.D., engaged in a competitive developmental effort to produce a sensitive screening battery specific to mild cognitive deficiencies – deficiencies that would be sufficient to potentially impair skill and aviation performance. From the viewpoint of aeromedical certification such a tool could be used to ascertain damage and to provide an objective (and relatively inexpensive) assessment for determining sufficient recovery from head trauma or brain disease to consider reinstatement of a pilot's withdrawn medical certificate. The Georgetown University model, called COGSCREEN, was the result of that effort. The value of the test not only for aeromedical certification purposes but also for assessments of persons in a variety of occupations which require highly skilled cognitive capabilities is attested to by the patenting and commercialization of the test by Georgetown University; it thus represents another successful transfer of technology. ❑