

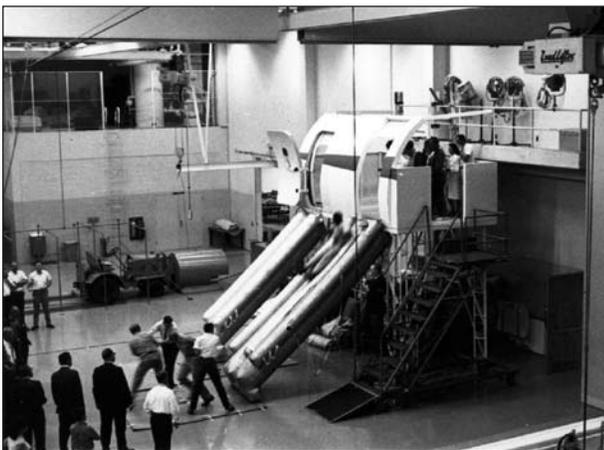
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## Protection and Survival ... Saving Lives

With the establishment of the Protection and Survival Laboratory in CARI, John Swearingen's small team from CAA days was increased and its capabilities expanded. The driving forces during the 1960s and '70s for areas other than the research by Swearingen were Richard F. Chandler, who became laboratory chief and CAMI's researcher for crash injury protection, J. D. Garner, who specialized in emergency evacuation issues, and Ernest B. McFadden, whose forte became oxygen equipment and flotation devices. It would be difficult to overestimate the significance of the contributions of all these men. Chandler significantly extended the testing of child seats including the development and use of scientifically adequate child dummies (until then, even automobile crash studies used dolls). He also evaluated a number of seat restraint systems for general aviation aircraft as well as an energy absorbing steering column technology for possible application to aircraft controls. Garner and McFadden, in addition to their specialty areas, had regularly worked together as a team in addressing survival of flight crews and passengers in commercial aircraft. They had tested smoke hoods and had begun assessing computer simulation of emergency evacuations as early as 1970. Later, they conducted escape studies with blind travelers using canes and with passengers who had mobility handicaps; they conducted studies evaluating the needs and effectiveness of infant and child flotation devices. After their retirements, research on oxygen needs and equipment was continued by physiologist E. Arnold Higgins, Ph.D., while studies of passenger emergency evacuation for the past decade-plus have been led by G.A. McLean, Ph.D. (including a Type III overwing exit study that used 2,544 subjects).

*AN INSIDE JOB. Early CARI/CAMI evacuation tests were conducted in the high bay area. Tests using various door heights are shown below and at right.*



*COMMUNICATING. McFadden (center) discussed results from the latest altitude chamber testing of oxygen mask equipment in a 1974 meeting of the SAE-A10 (aircraft oxygen equipment) committee held at CAMI. Committee chairman Jules Duval (TWA – Kansas City) and Humphrey Hamlin (Normalair – Garrett, Ltd., England) were the interested listeners.*

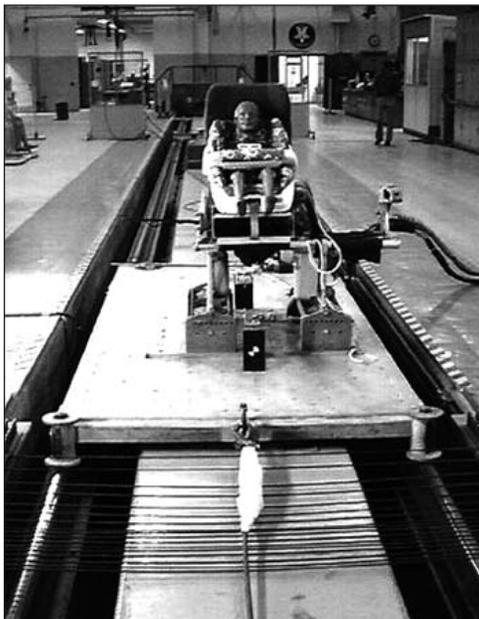
Work in these various protection and survival areas has always been based in cooperation and coordination with aviation safety groups and equipment developers. Prime among these (oddly enough) have been the various specialty groups in the long-established Society of Automotive Engineers (SAE); now known as SAE International. Various committees within that organization's (now) Aerospace Division, such as SAE-S9 (cabin safety provisions), SAE-A10 (aircraft oxygen equipment), SAE-A20 (aircraft lighting), SAE-G10 (aerospace behavioral engineering technology), and the SAE Seat Committee,



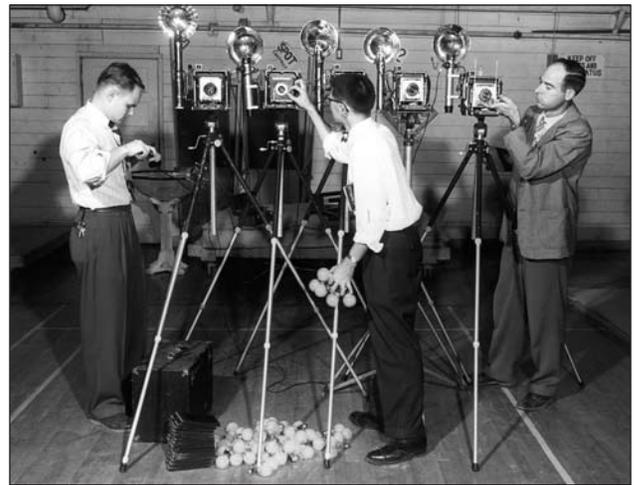
continue to be major sources of regular interaction for CAMI's scientists. These interactions help to account for the fact that, from its CAMRL beginnings to the present, so much of the protection and survival research has been translated into rules and regulations, improved safety systems, and improved manufactured products from oxygen masks and restraints to emergency lighting.

### Crash Injury Research

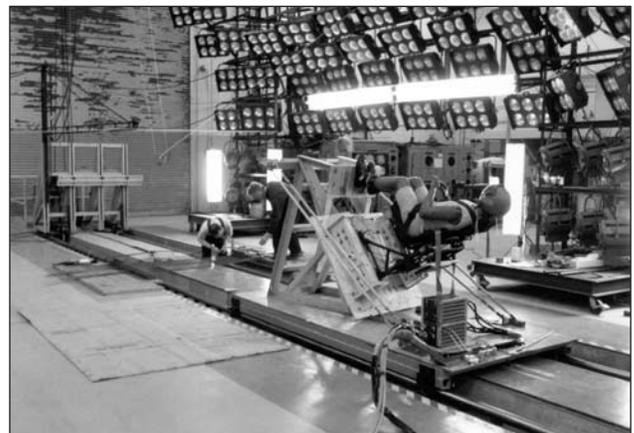
Chandler introduced a new direction in CAMI's crash injury research programs. Part of that direction involved his upgrading of the 2-rail track that ran the length of CAMI's spacious high bay area. He designed unique test equipment, installed new instrumentation, and substituted heavier duty rails for the existing ones. "The Track" thus had the capability for the dynamic evaluation of seat and restraint system performance. Briefly described, two precision rails (140 feet long) with a winch and wire brake system accommodated a sled that could be propelled to a high speed and then brought to a sudden stop (in 200 milliseconds). The sled permitted the attachment of various seat and restraint configurations as well as instrument panels and cockpit enclosures, as desired, along with instrumented dummies. His development and use of dummies that would provide the best information on injury patterns permitted the formulation of recommendations regarding dimensions, location, and tie-downs that would prevent or reduce injuries and death from crashes.



*"THE (RIGHT) TRACK." CAMI's sled tests used in crash impact studies conducted on "The Track," viewed here from the braking system at the end of a run.*

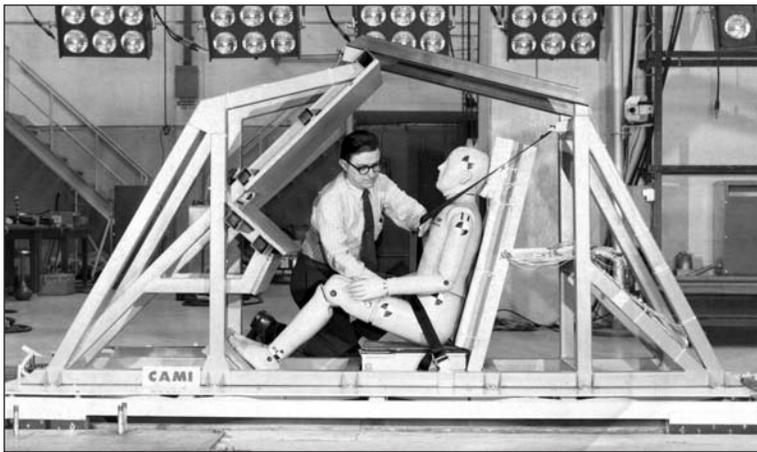


*THEN AND NOW. Early approaches to documenting impact tests involved a set of cameras with split-second timing sequences. With the advent of high-speed motion picture (then video) technology and other electromechanical advances, a state-of-the-art CAMI system was kept in place.*



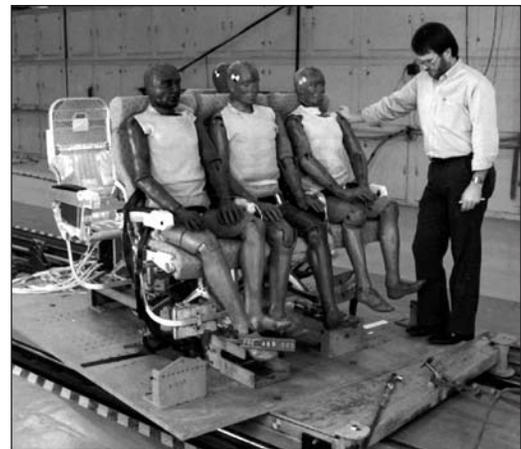
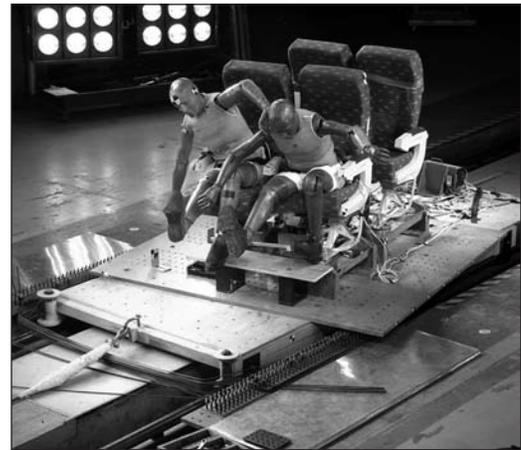
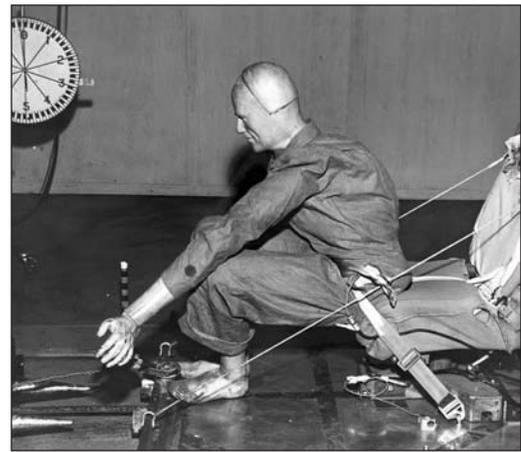
Chandler also extended CAMI's involvement with the military, testing prototypes of a 2-passenger helicopter seat for the U.S. Army Aeromedical Research Laboratory, and prototypes of energy absorbing helicopter seats for the U.S. Air Mobility Research and Development Laboratory, the U.S. Navy, and the U.S. Coast Guard, as well as an energy absorbing passenger seat for NASA. He also expanded cooperative development efforts for seats in civil aircraft by working with all of the major manufacturers. That work provided the basis for a complete revision of the FAA regulations for seat, restraint, and crash injury protection systems in aircraft. The new regulations were adopted in 1988 and represented the first significant revision since 1927.

Chandler's personal involvement with impact issues and seat-and-restraint integrity was subsequently assumed by engineer Roy Van Gowdy who continued to add to



*Keeping It Moving. Chandler expanded on Swearingen's impact studies and introduced improvements to "The Track"; he remained a widely sought expert on seat safety and restraint systems after his CAMI retirement.*

CAMI's perceived excellence by the aviation industry and federal regulators through his extensive work with both U.S. and foreign airlines and manufacturers, with NASA, and as a major visiting consultant to other countries that were establishing their own impact test facilities. Those visits include his presenting classes on dynamic impact test procedures and FAA crash worthiness seat regulations at the Civil Aero Polytechnology Institute in Beijing, China, and to the Australian Civil Aviation Authority and aviation industry representatives in Sydney, Australia. Richard DeWeese recently succeeded Gowdy as head of that program.



*MORE IS BETTER. With improvements in track materials, more seats and dummies could be tested at one time. Work by Chandler and Gowdy frequently used multiple "passengers."*



*NASA NEEDS. Impact tests conducted by DeWeese (l) and Gowdy (r) in support of the NASA program occurred during the '90s. A NASA flight suit (l) was used on the dummy in one set of trials.*



### "Smart" Dummies

A significant aspect of impact research involves appropriately constructed dummies. Oscar (retired in 1963) and Elmer (built by Swearingen in 1949 and 1950, respectively) were carefully weighted, articulated, and incorporated other elements that put those dummies in high demand for borrowing or copying by military and commercial laboratories. And, in perhaps one of the earliest substantive acknowledgements of diversity in



*LIKE THE OLD MOVIE. (above) In a scene somewhat reminiscent of old black-and-white monster movies, Jack Blethrow repaired Elmer after a crash study. (r) Judy Anderson applied hair spray to Sierra Suzie – the first female model of a crash dummy used on “The Track.”*



technical aeromedical settings, a female dummy (Sierra Suzie) was in use at CAMI by the early 1970s.

The development of impact research dummies that provided the best possible human representation was an ongoing effort. Designs developed at CAMI, particularly by anthropologists Clyde C. Snow, Ph.D., and Joseph W. Young, included criteria for head and face anthropometry, body forms for children, and an anthropometrically accurate pelvis structure, (the “golden pelvis”) – the latter two efforts were in support of the National Highway Traffic Safety Administration (NHTSA). These advances were capitalized on by others (e.g. the U.S. Air Force) conducting crash research. An early cooperative program

with the U.S. Air Force to determine mass distribution properties of the human body developed three dimensional anthropometric measurement techniques. The Air Force adapted that technology to computerized scanners and used it as the basis for Project CAESAR, the first world-wide survey of human body size to utilize three dimensional measurement. The design modeling of anthropomorphic test devices was a multi-decade CAMI effort that had applications to fields other than civil aviation.

#### **Focus on Children**

Proper protection of children has always been a major consideration. Based on identified needs, dummies representing 6-month-old, 2-year-old, and 3-year-old children were both designed and used extensively by CAMI and also by NHTSA. And, stimulated by Chandler in the late ‘70s with the support of NHTSA, anthropological measures, including biostereometric mapping, by Young and Snow from groups of 2½ – 6½ year-old children led



*ALMOST REAL. (l) Young at work on the “golden pelvis.” Accurate pelvis representations in dummies permitted a more precise evaluation of injury in various crash scenarios.*

to the production of new 3- and 6- year-old body forms – NHTSA’s “golden shells.” These were not dummies in the usual sense but, rather, body forms to test the fit of restraint systems. Work to improve the information from the CAMI-developed dummies continued well past their first use. For example, in the mid-90s, DeWeese designed an experimental device to measure abdominal pressure in the 6-month-old and 2-year-old dummies in dynamic impact tests of child restraint devices.

CAMI’s research with dummies on “The Track” had shown the hazards of a passenger holding an infant on her lap during an aircraft crash – the child cannot be held because of the G forces and becomes a projectile. The use of automobile restraint devices for children was initially thought to be an immediate solution, but CAMI



*CHILD CARE. Gowdy in one of his many tests of infant seat protection.*

research showed many of these devices to be acceptable for automobile use but inadequate for crash protection in aircraft. CAMI’s work, led by Chandler and Gowdy, led to the defining of criteria and development of prototypes for proper infant and child protection in aircraft. In 1985, NHTSA began approving child restraint systems for use in autos that were also acceptable for use in aircraft, based on the CAMI data from tests on “The Track.”

### **More Anthropology**

Swearingen’s somewhat circumscribed use of body measurements in research was extended by Richard G. Snyder, Ph.D., who collaborated with fellow anthropologist Snow in a mid-1960s study that involved extensive anthropometric measures of air traffic control specialists (ATCSs). The results were to provide a data base for the design of ATCS work space and equipment, a long-range study of the aging ATCS population, and

to explore relationships between physical condition and performance effectiveness. Later, in the mid ‘70s, Snow initiated an extensive anthropometric study of flight attendants based on the perceived need to address the (then) stewardess’ work station and surrounds with base line data (e.g., for determining the proper size, height, load relationships, fold-up criteria, and other features of the various types of seats used by flight attendants). That study drew a press conference response from Senator William Proxmire, who cited it for one of his many “Golden Fleece” awards. The “awards,” which he periodically publicized for more than a decade, represented the senator’s view that certain research projects represented frivolous uses of taxpayer money. The senator may not have been aware that the research was in response to findings of a study reported by the Air Line Pilots Association. That study comprised 103 accidents/incidents involving emergency evacuations in which flight attendants had identified 471 problems including various issues related to seat construction and location, inadequate restraint systems, inaccessible emergency equipment, megaphones that were too heavy, lack of head padding, and others. In any event, the CAMI study provided the anthropometric data for use by the aviation industry. Remarkably, almost three decades later, an editorial in the prestigious weekly journal *Science* addressed some recent political ridiculing of government funding for a variety of research projects and cited the CAMI study “of the physical characteristics of flight attendants that ultimately led to the development of life-saving safety belt configurations for them” (32) as an example of how short-sighted such criticism can sometimes be.

Parenthetically, Snow had worked on the development of forensic methods for identifying human remains from aircraft accidents (8). As his knowledge and skill in this area became known, he was often called upon by state and local law enforcement to assist in identifying remains. These interests led him to provide training and encouragement to one of CAMI’s medical illustrators – Betty Pat Gatliff – whose avocational pursuits included proficiency in sculpture. Snow provided guidance and stimulated her to work on reconstructing facial features on skulls for forensic identification purposes. Gatliff became so skilled at the art that, following her retirement from the FAA, she became a nationally sought expert, lecturing around the country. And when Snow retired from federal service, he rapidly became an internationally recognized expert in forensic anthropology. He has been a key figure in major criminal cases in this country and in war crimes cases in other parts of the world.

## Escape Procedures: Phoenix...and the SST

Some of the more exciting CAMI research involves tests related to the emergency evacuation of passengers from downed aircraft. During the '60s, much of that work was conducted inside, in the high bay area of the CARI building. One major exception was an evacuation study conducted with a crashed Lockheed L-1649. That study, in 1965, was part of an FAA crash test safety research program with the Flight Safety Foundation. Instrumented dummies, onboard during the actual crash a year earlier, were replaced by "passengers" who experienced a one-hour "flight" (including box lunches) and a "crash" simulated by use of artificial smoke and crashing sound effects and enhanced by some purposely jammed door and escape hatches. Motion picture cameras, remotely controlled both inside the aircraft and exterior to it, and precision



*THEY'RE CALLED "SLIDES." Not all proposals for using early versions of inflatable slides for emergency evacuation proved to be useful. CAMI research defined an ideal angle of 27° for safe, rapid evacuation (28).*

timers provided much of the data. Results assessed some features of seat spacing and aisle widths and provided a planning base for future studies of evacuation procedures from a damaged aircraft.

A unique series of evacuation studies involved the configuration of a supersonic transport (SST). When a government contract to build an SST prototype went to Boeing and, later, the U.S. opted out of the international supersonic transport competition, CAMI secured the Lockheed model – a wooden structure – and Garner took advantage of the opportunity, in 1967, to assess escape procedures in an SST configuration that would accommodate 280 passengers and 9 crew members. Those tests used exits of various dimensions and resulted in support for establishing the Type A exit (minimal opening 42" x 72") for wide-body aircraft, such as the 747, and eliminated the Type IV exits (minimal opening 19"

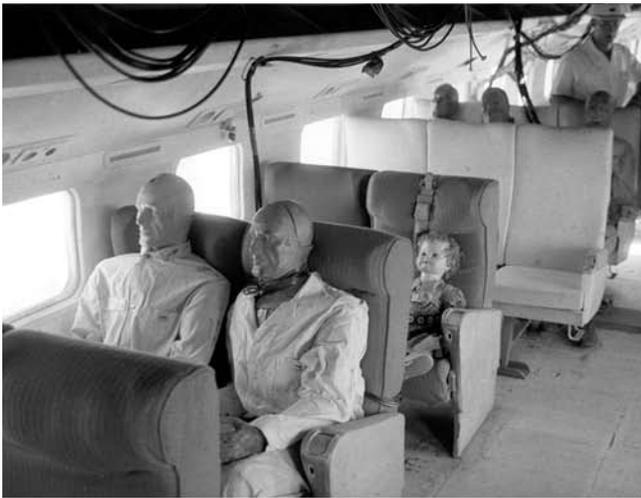
x 36") as being too small. The model was also used for other outdoor evacuation tests until CAMI acquired a C-124 fuselage and an attitude positioner.

## Emergency Evacuation: The CAMI Facility

In 1970, with the acquisition by Garner of the C-124 Globemaster fuselage, donated by the Oklahoma Air National Guard, and the installation of a positioning system (at that time, the only one of its kind in the world and, currently, with features of size and flexibility still not duplicated anywhere), emergency escape procedures could be tested under conditions where the angle of the fuselage, the interior environment, and the complements of passenger load could be varied. Since then, studies of ground level evacuations and those using slides have been conducted in CAMI's Aircraft Cabin Evacuation Facility (ACEF) to test various specific aircraft conditions including the dimensions of exits, aisle widths, seat configurations, separation of seat rows, location of seated passengers, location of exits, use of spiral staircases vs. a straight staircase with a single 180° turn in double-deck aircraft, role of flight attendants, presence or absence of smoke, and other conditions. All of these studies contributed to the validation of dimensions, configurations, and procedures directly pertinent to the emergency evacuation of aircraft. (Also relevant to safe evacuations is the work of CAMI's toxicology laboratory on flammability and heat-induced toxicity of the materials used in aircraft cabin interiors.)

## Useful Applications

A significant, related CAMI effort regarding emergency evacuation involves joint training and research agreements initiated by a member of the cabin safety team, Charles B. Chittum, with the USAF 552<sup>nd</sup> Air Control Wing, begun in 1989, and with the USN Strategic Communications Wing, begun in 1993. Both military groups are located at nearby Tinker Air Force Base in Oklahoma City. Through 1999, Chittum provided, on a monthly basis, intensive aircraft emergency evacuation training (2 classroom hours plus 1 hour of experience in both a clear-air and a smoke-filled cabin); for their part, the airmen agreed to serve as research subjects for CAMI evacuation studies. By the time the 2000<sup>th</sup> USAF airman had completed the course (1994), 500 of them had participated in three CAMI studies and another 8,000 "students" (from groups such as the American Association of Airport Executives, aviation medical examiners, Airport Travelers Aid, Explorer Scouts, high school and college students in aviation careers, and many others) had completed Chittum's program. To date more than 9,000 military airmen have been trained in the program, which is now conducted by Jerry R. McDown.

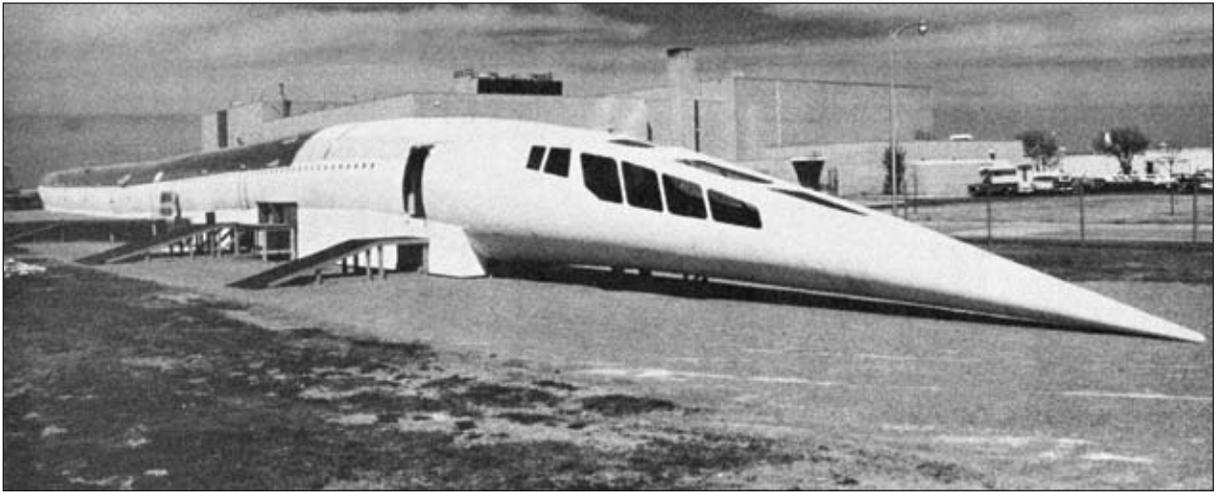


In 1964, the FAA crashed two “scrap” aircraft with dummies to test various survival issues.

### THE “PHOENIX CRASH” TESTS

In 1965, a unique CAMI evacuation test (headed by J. D. Garner, below, far right) was conducted using one of the crashed planes.



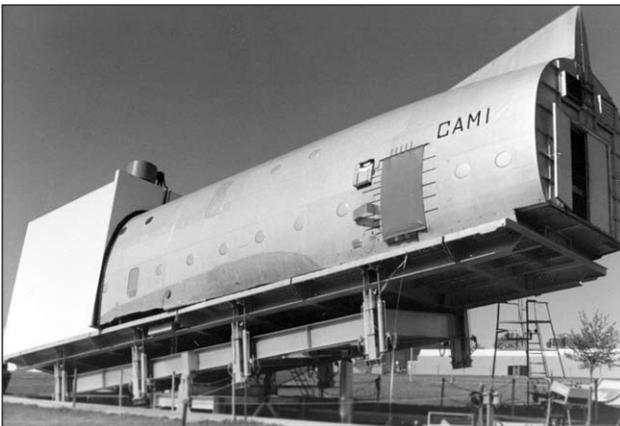


***SST ESCAPE PROCEDURES***



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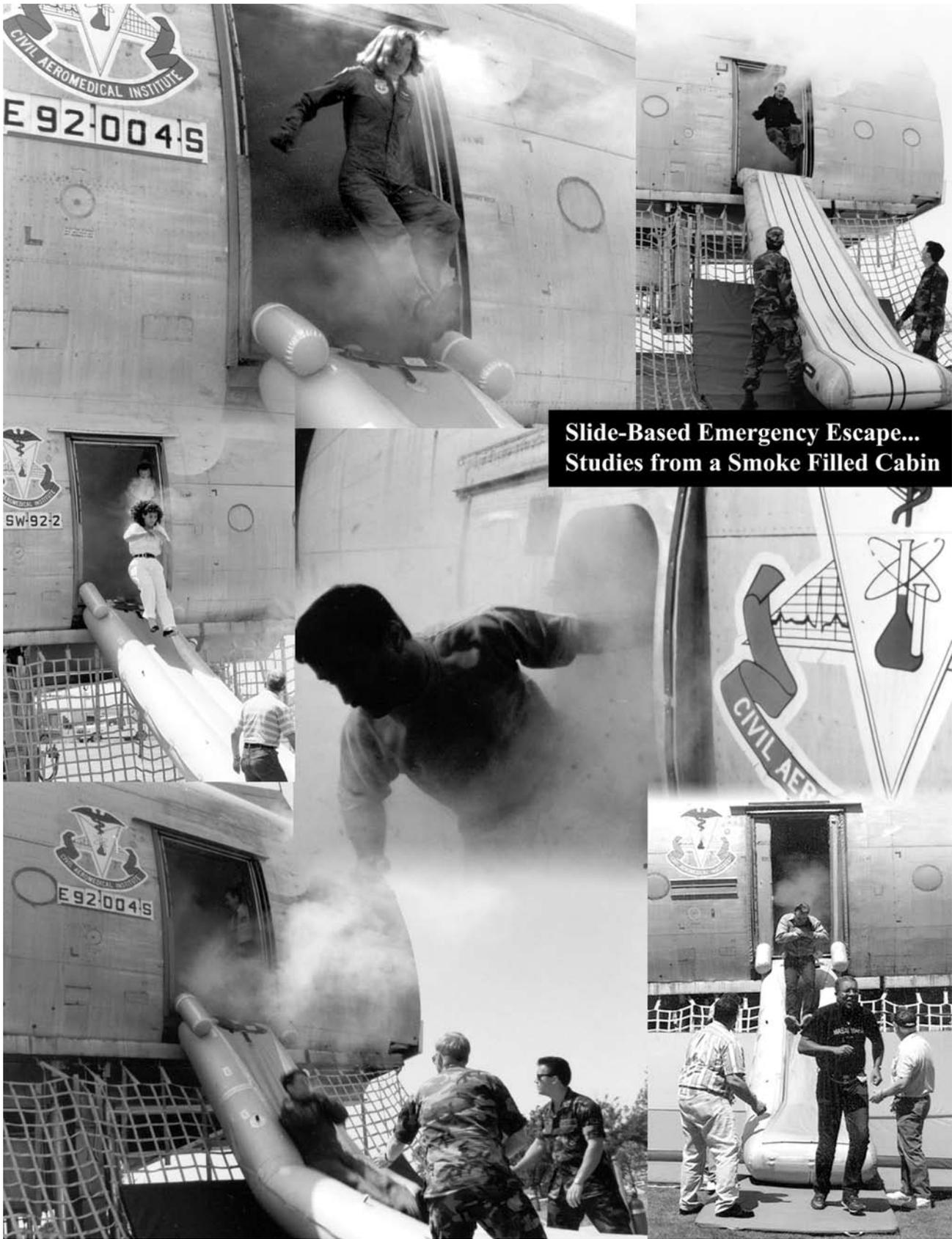


*GETTING OUT. CAMI's unique Emergency Aircraft Cabin Evacuation Facility (ACEF) was developed with an eye to the future. The attitude positioner was designed to accommodate larger aircraft than the original Globemaster – i.e. wide-body jets. The first evacuation tests with the C-124 are shown here.*





**Ground-Based  
Emergency Escape Studies**



**Slide-Based Emergency Escape...  
Studies from a Smoke Filled Cabin**



*20,000 By 1999. Chittum briefed this group of aviation medical examiners prior to their experience in evacuating a smoke-filled cabin. By 1999, when he retired, groups of various sizes comprising a total of more than 20,000 persons had been exposed to his survival training.*

Parenthetically, Chittum's evacuation training demonstrations and clearly delineated principles of survival were so well crafted and presented that his presentations became a focus for news media from around the country (particularly during TV's semiannual "sweeps week"). While CAMI's cabin evacuation capabilities had a long history of generating periodic media interest, 20 or so TV stations from various cities sent crews to CAMI through the '90s, and taped these briefings/demonstrations for showing as special evening news features on "surviving a plane crash." Additional teams taped Chittum's "how to survive" guidance for major network TV programs – Hugh Downs' "20-20," Peter Van Sandt's "CBS World News Tonight," Dateline, and a German TV news program, as well as People magazine, The Washington Post, and other media outlets. That safety information and assurance, based on CAMI research, reached millions of potential air passengers.

Another application from CAMI involved the 1975 development of Cabin Safety Workshops by Donell Pollard (whose background included experience as a flight attendant). The workshops were begun in earnest in 1976. Initially they were designed as a more efficient way of providing to frequent visitors from the airlines the type of safety and survival information they regularly sought from CAMI, and to make available to all the airlines specific useful information that each might have accrued individually (44). The concept became immediately popular with both the airline industry and the flight attendant unions. Thus, what was originally proposed as several small group workshops per year grew to several (sometimes more than a dozen) very large workshops a year with an average of 125 attendees annually (44).

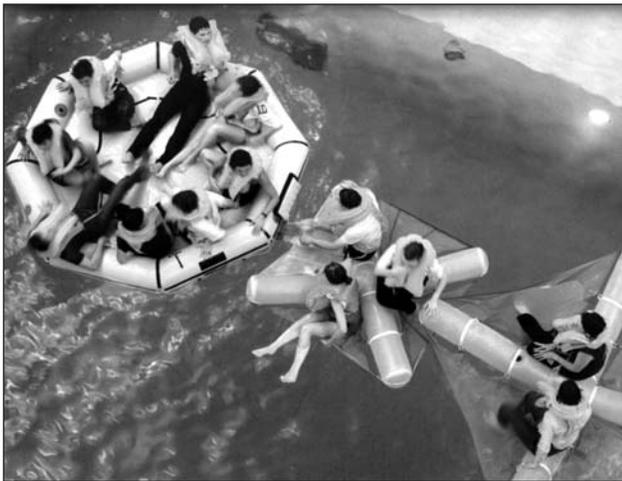
Ultimately there was participation from every U.S. airline and most major foreign carriers. The 3½ day sessions came to include the application of FAA policy, rules, and CAMI research. There was a structured exchange of information on airline emergency procedures, followed by related research findings presented by Pollard. (Pollard also used some of the discussion outcomes to suggest potential research questions to laboratory chief Chandler). Other topics included G-force dynamics and crash injury protection (restraint, bracing, and special needs of children), protective breathing equipment, and experience in the evacuation simulator (the smoke trials were considered particularly informative with regard to emergency lighting issues). These experiences were followed by physiological training (including altitude chamber runs), water survival, and presentations of other applicable research findings, including data from CAMI's aircraft accident investigators.

Attendees have included line flight attendants, emergency procedures instructors, pilots, crewmember union safety representatives, airline officers of several levels, FAA safety inspectors, and others with a specific interest in aviation safety. Pollard scheduled and conducted these workshops until 1987 when she transferred to FAA Washington Headquarters, but continued to participate in them until her retirement in 1999. Mark George, who had worked with her during 1984-1986, took responsibility for continuing the workshops, with her participation in selected sessions, until he joined the NTSB in 1998; he has been succeeded by David A. Palmerton.

Pollard also created a Cabin Safety databank, based on analyses of FAA accident/incident reports. The databank contained information on seat failures, slide malfunctions, occupant injuries during turbulence, evacuation related injuries, and other similar material. This information was used in the workshops and also in other FAA activities including policy development and research.

### **Water Survival**

The conditions of a crash may require additional survival efforts after successfully evacuating a downed aircraft – as when a crash occurs in water rather than on land. CAMI's ditching pool provided McFadden with data regarding not only escape procedures, but also the efficiency of water survival equipment such as life rafts and flotation devices. Many other tests of rafts and flotation equipment were conducted in Oklahoma City area lakes by McFadden and his team. However, one set of studies was completed at Siesta Key, Florida – "laboratory" studies at the Mote Marine Laboratory using its captive sharks, and "field" studies in the See Sea, an underwater observation vessel of the Naval Undersea Research and Development Center, conducted in shark-infested wa-



*WATER SURVIVAL. Escape and survival equipment and procedures tested in the CAMI ditching tank ("pool"), on a clear lake, and in turbulent water.*

ters off the coast of Florida. One particularly interesting finding was that sharks were attracted to some degree to the bright orange underside of rafts. McFadden's solution was to produce rafts with dark undersides and to replace some chrome and other reflective sections of life vests with black, non-reflective material.

### **Smoke Hoods**

CAMI began developmental work on smoke hoods as early as 1965. This approach was designed to reduce or eliminate the likelihood of expiring from smoke inhalation while attempting to escape from a burning, downed aircraft. The specific genesis of these studies resided in two aircraft accidents within a one-year period in which a number of passengers who survived the impact died of smoke inhalation. A "get-me-out" device was the term used by McFadden to describe the purpose of this early work and the prototypes he designed and tested. In addition to providing a reasonable supply of air and

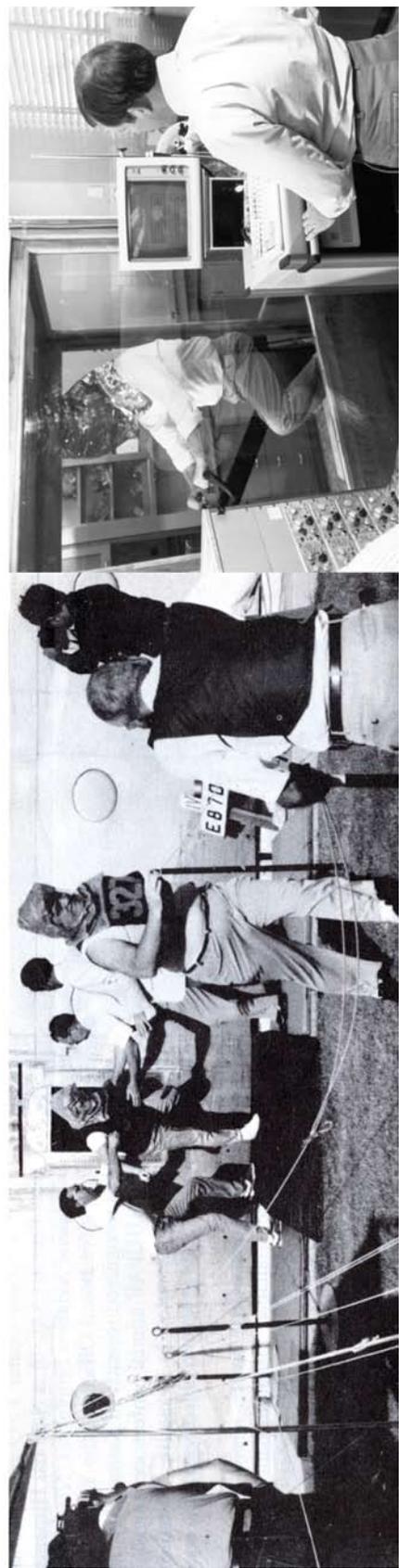
protection from breathing smoke, the hoods would have to permit visibility and protect against both heat and fire. McFadden's confident demonstrations of one of his devices with a blowtorch applying a 1,200-degree flame directly into the face of the translucent hood covering his head were breathtaking. Although the hoods were not adopted for use at that time, interest was regenerated after the 1983 Air Canada in-flight fire that resulted in a landing at greater Cincinnati airport with half of the passengers dead from smoke inhalation. Then in 1985, 55 passengers died as the result of a fire aboard a Boeing 737 on the runway at Manchester, England. Those events spurred CAMI to conduct additional tests of more advanced designs. By the '90s, virtually all carriers had standard protective breathing equipment for crewmembers for fighting fires.



**CAMI'S SMOKE HOOD INITIATIVES**

Proof Testing. Successful evacuation tests of McFadden's early versions of a smoke hood were conducted in 1968 in an Aeronautical Center hangar using a borrowed commercial aircraft to provide a type of "proof of concept."

(Below) Following a resurgence of interest almost two decades later, additional tests were conducted in 1987 using CAMI's ACEF facility; smoke hoods had attached air supplies and the evacuation route involved small escape doors. Laboratory studies by McLean in 1989 assessed the integrity of the hoods by measuring respiration and heart rate while the wearer was stationary and during exercise in a chamber that exposed the wearer to gas combinations (oxygen and sulphahexafluoride).





*TRUE BELIEVER. McFadden's demonstrations of the capabilities of his smoke hoods to withstand heat and fire were memorable as well as convincing.*

### **Smoke, Darkness, and Emergency Lighting**

Thorough tests of lighting schemes to aid passengers in evacuating a downed aircraft that is dark and/or smoke-filled were significant CAMI contributions to improving safety. Around 1974, Garner and McFadden had apprised George Plumly, a successful Fort Worth, Texas, engineer/inventor with expertise in lighting, of the need for a lighting system that would significantly improve passenger evacuation rates in smoke-filled aircraft cabins (28, 34). Plumly agreed to explore the idea at no cost to the government and began an informal, intermittent working relationship with CAMI that lasted a decade or more.

Because the industry seemed reluctant to mount any system on the floor (perhaps because of perceived issues related to maintaining system integrity), Plumly (who's Plumly-F and Plumly-FX lighting systems had, by 1975, shown superiority to other systems) and CAMI (between 1979-1981) initially tested, in smoke-filled cabin conditions, a variety of spotlights, strobe lights, and self-illuminating markers, located at or below the cabin midpoint as well as lights in seat arm rests, and found them to be ineffective (43). These same elements and others, including strip lighting on the floor, were later tested at the FAA Technical Center facility using smoke from burning jet fuel in a totally gutted aircraft interior with an observation booth at each end of the cabin, including closed circuit television, and motion and still pictures (15). Because dense smoke in a cabin rises and stratifies, and its vision-restricting concentration takes longer to reach floor level, the foregoing sets of studies

indicated the need for illumination in close proximity to the floor to aid passengers in exiting quickly and safely. (Parenthetically, as part of his last project before retirement in 1979, Garner had explored the utility of floor lighting by [shades of the old CAMRL!] placing flashlights along the aisle floor.) Then, in November 1984, Plumly conducted some "unofficial" smoke tests on a 20-foot functional prototype of his floor strip-lighting unit – the Plumly Advanced Egress Lighting System – in a static Boeing 707 at the FAA Technical Center followed by three sessions at CAMI, two of which followed installation of a complete floor strip system in the cabin simulator (42). While these tests were not described in any government research reports, they were described in formal reports by Plumly Airborne Products, Inc., (42), and the CAMI outcomes were observed by a number of interested parties including representatives of the American Society of Illumination Engineers and an FAA rule-making team (8).

Prior to the CAMI sessions, the FAA rule-making team, headed by Henri Branting (16), had participated in one test of a proposed solution to the egress problem: a small point of light, located on the armrest of each aisle seat. During the test conducted in pitch darkness, the FAA team's walk-through convinced them that such an arrangement was not effective. It provided no depth perception and gave the impression that each step was into a black hole (4). The later tests of the installed floor lighting and other lighting arrangements, provided to Branting on two occasions by Chittum and Chandler, used CAMI's smoke evacuation paradigm. CAMI's work showed that "passengers" could follow the floor lighting in a smoke-filled cabin and could recognize the exit from the aisle.

Those practical CAMI evacuation demonstrations in dense smoke influenced the Branting team positively regarding the value of floor strip lighting and gave them



*FLOOR LIGHTING WORKS. As a cabin fills with smoke, it stratifies from the ceiling down. Thus, upper level emergency lighting is obscured well before the floor-lighting "pathway" to an exit.*



*DIVERSITY MATTERS. (above) Safety procedures for emergency evacuation of the physically challenged and equipment that accommodates the youngest and the oldest have been studied. Pictured below are McFadden with one of his flotation devices for children and Snow testing force capability for push-button seat belt releases.*



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“the confidence to proceed” with the implementation of the final rule (4). Floor proximity lighting became mandatory in 1986. But that did not end CAMI’s interest in the area; with advances in photochemistry, the feasibility of using modern photoluminescent materials as lighting sources was re-evaluated by McLean in 1998.

### The Young, the Old, and the Handicapped

Swearingen, Chandler, and Gowdy all worked with children as a special-need group with regard to seat/restraint integrity and all pioneered in the development and use of child dummies in aircraft crash protection studies. However, in addition to impact and evacuation studies, other CAMI research has focused on small children. For example, McFadden’s work with flotation devices included special studies of the needs of infants and small children (air carriers did not then carry infant devices; a few now do). While buoyancy and stability are critical characteristics of any flotation equipment, infant flotation devices require reliable self-righting. McFadden’s assessment of then-current life preservers for children indicated adequate flotation and stability in the unperturbed water of a test pool, but relatively simple movements (such as raising the arms above the head) could be sufficient to change a small child’s center of gravity and cause the child to rotate and perhaps submerge its face. Another issue was water temperature. Compared to adults, small children exposed to cold water have a significantly reduced survival time because of their low total body weight (and, therefore, low body specific heat) and their large surface area per unit of body mass (2-3 times that of an adult).

Thus, McFadden went about creating devices that would address the needs for buoyancy, stability, self-righting, and thermal protection, as well as providing ventilation, impact protection (tested by a required self-righting of the device containing a dummy when released in an inverted position from cliffs 13-21 feet above the water), and protection against predatory marine life. McFadden evaluated various types of infant flotation equipment that he devised using an available anthropomorphic dummy, representative of a 3-year-old, and dummies that he developed to represent children from 4 months to 2½ years of age. Data from Swearingen’s studies of the centers of gravity of small children and of infants were central to this process. McFadden’s work provided a template for safe infant flotation designs. Later work with flotation equipment was headed by Gordon Funkhouser.

Evacuation studies have also dealt with small children, as well as the elderly and the handicapped. While elderly subjects have routinely been a part of the passenger age mix in most of CAMI’s evacuation studies, special attention to infants and small children began with Garner in the mid ‘60s and continued with preliminary work



*MODEL WORKER. Funkhouser working with one of CAMI’s specially constructed child dummies in assessments of the performance of various flotation devices for infants and children. In addition to performance in the water, design features, such as strap locations, may influence donning time (which would require the assistance of a parent or other adult) – another critical safety issue.*

by Chittum (unpublished data presented at a national meeting on child safety) followed by a recent set of studies by Cynthia L. Corbett. The first of this set evaluated evacuations using a single lane slide from a Type I exit; the second assessed the safety techniques for evacuating an infant through a Type III overwing exit. These studies used dummies representing children between 2 and 24 months of age and led to the identification of appropriate procedures and guidelines to recommend to passengers with infants.



*TOUGH SLIDING. An FAA employee wearing a faux cast tries to navigate an evacuation slide.*

With respect to the handicapped, land evacuation studies have included the blind, with and without canes, and persons with a variety of other physical and mental conditions that might influence safe evacuations. Such subjects were recruited through various local organizations (e.g., the Oklahoma League for the Blind). In addition, various types of handicaps were simulated by FAA employees or other nonhandicapped subjects (e.g., by wearing faux arm or leg casts) and by the use of dummies that other “passengers” would have to “assist.” Issues related to aisle widths, seat sizes, seating arrangements, floor slope, grouping of passengers, and other evacuation features were evaluated.

### New Thrusts

An additional research tool was added to the protection and survival programs in the late ‘90s. As part of an approved capital project headed by Jerry R. Hordinsky, M.D., (then head of the aeromedical research division), a retired Boeing 747 was procured and refurbishing begun under the direction of engineer Jeffrey H. Marcus who replaced the retired Chandler as head of the protection and survival laboratory. (Marcus was also overseer of the installation at CAMI of the United States’ first – and clearly most advanced – new altitude chamber in 25 years). Refurbishing of the aircraft was completed in 2001 with some new lines of work defined by James E. Whinery, Ph.D., M.D., the new Aerospace Medical Research Division chief. One of the new directions involves the capability of research on cabin airflow that will permit the assessment of air quality (e.g., dispersion of microorganisms and of air contamination from internal and external sources - including acts of terrorism).

The facility has already been used by the protection and survival staff (now headed by Robert Shaffstall) in support of a NASA contract to develop an early warning system for detecting air turbulence; that study determined times required to secure a passenger cabin following an air turbulence warning. The facility is also in periodic use as a training vehicle in support of courses conducted at the adjacent Transportation Safety Institute (TSI); that TSI training includes security personnel (dealing with potential hijackers and unruly passengers) and aircraft accident investigators.

Another new thrust deals with the establishment of bioinformatics research in which computer databases and models are being developed for the simulation of crash dynamics, cabin evacuation, cabin air flow, and the reconstruction of aircraft accidents and aerospace incidents. (The latter approach has similarities to that of CAMI’s SATORI, used in investigating air traffic



*CAMI's 747. First Uses: (above) TSI training and (below) NASA's turbulence study.*

control operational errors and incidents.) An additional bioinformatics effort is the development of methods for analysis of large data sets – an approach that will have application to aeromedical certification in addition to protection and survival areas.

Another particularly timely area of new work was the assessment of the effects of laser lights on pilot vision and control of aircraft. Van Nakagawara, O.D., has examined both the clinical aspects of laser light exposure as well as the subjective effects of exposures (below levels that might cause tissue damage) on vision and operational performance in the Aeronautical Center's Boeing 727-200, Level C, full motion flight simulator. Nakagawara's work with issues related to laser lights beamed from the ground into cockpits during night-time flight operations was undertaken based on the accumulation of some initial reports and well before such dangerous events attracted national media attention. As a result of identifying the magnitude of the problem early, timely CAMI information and suggestions were available to the FAA and the Department of Transportation. Levels of laser light that would be unacceptable at different stages of flight were defined to assist in developing safety precautions. □

## Air Traffic Controllers: Stress ... and Sleep

### The Issue Was Job Stress

During the '70s, concerns regarding passenger safety, perceived work stress associated with the air traffic control occupation, and controllers' mental states became a media focus ("Sweaty Palms in the Control Tower" was the title of one such article during that time) and a major labor issue (11, 36). A team of CAMI physiologists, led by Carlton E. Melton, Ph.D., and a CAMI psychologist, Roger C. Smith, Ph.D., combined to perform an array of on-site studies that ultimately included a total of 402 air traffic control specialists (ATCSs). The studies embraced different types of air traffic facilities and permitted comparisons between them and between different shift schedules, different traffic volumes, and the effects of introducing ARTS-III.

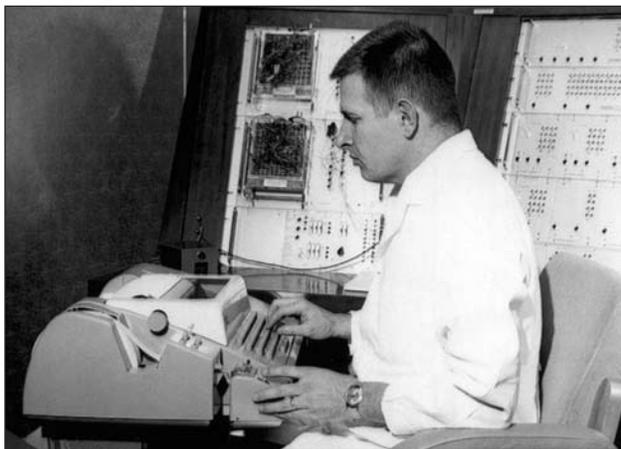
Physiological tests were extensive and complemented by psychological assessments of job attitudes and of perceived stress. Data obtained included ambulatory electrocardiograms (ECGs), urine samples analyzed for 17-ketogenic steroids, epinephrine, norepinephrin, and creatinine, fatigue check lists, and questionnaires regarding medication usage, physical complaints, and sleep reports. Physiological results showed clear stress effects related to periods of increased traffic volume (i.e. increased workload) both within and between facilities, but no pervasive or unacceptable levels of general "stress-induced" outcomes.

The psychological tests resulted in profiles that showed controllers to be particularly well-suited to their occupation; their work preferences tended to be for moderate-to-heavy traffic rather than for lighter levels. They liked the difficulty of the work and the constant traffic

change. They did not like light traffic, night shifts, and management. The research effort was wide-ranging. It included field studies at 22 air traffic facilities including the O'Hare air traffic control tower and facilities in



*MEASURING STRESS. (above) Air traffic controllers were monitored for stress while performing their daily jobs; the device worn by this tower controller provided electrocardiographic information. (below) Melton with physiological data recordings and (below, l) Smith during analyses of job attitude and stress survey data.*



Atlanta, Miami, Los Angeles, Oakland, Roswell, Oklahoma City, and others.

The sum of these studies documented anticipated physiological differences both within and between facilities related to variations in workload (e.g. by traffic count and radio transmission time). These differences appeared to be related more to general work activities than to excessive levels of stress associated with air traffic control work in particular.

### Sleep, Performance, and Work Schedules

Intimately imbedded in the stress issue was the question of shift schedules and sleep. This relationship is particularly pertinent to the air traffic occupation since enroute and terminal facilities frequently use a 2-2-1 shift (2 afternoons, 2 early mornings, and 1 midnight shift), a 2-1-2 shift (without a midnight shift), or a combination of both. These shifts are characterized as being “rapid turn-around” counter-clockwise shifts that make unlikely, if not unattainable, a full 8 hours of sleep before at least one shift a week (usually the midnight shift). It should be noted that, while most experts on work schedules consider the 2-2-1 shift to be undesirable, controllers given the choice of shift patterns often select the 2-2-1 because it provides the equivalent of 3 days off per week. However, in addition to health and stress issues, the rapid turn-around shift schedule involves circadian periodicity and begs the question of quality of performance and safety.

Early CAMI laboratory studies had examined the effects on sleep itself of exposure to simulated sonic booms

and the “jet lag” type performance effects of shifting sleep periods, while still others measured the performance effects of depriving individuals of a night’s sleep or more. Sleep deprivation of this sort had clear negative effects on the performance of laboratory tasks.



*At “HOME”... Studies in CAMI’s laboratories assessed performance with the Multiple Task Performance Battery and the sleep effects of counterclockwise rotating shift schedules.*



*... AND “AWAY”. FAA air traffic controllers from the Miami Center and U.S. Army and U.S. Coast Guard subjects worked with Della Rocco on the field studies of rotating shift effects and the introduction of scheduled napping.*

However, in the '90s, Pamela S. Della Rocco, Ph.D., initiated a set of laboratory and field studies to evaluate the potential need for and utility of fatigue countermeasures in air traffic control shift scheduling. The laboratory studies included assessments of performance, sleep, core body temperature, and neuroendocrine measures for conditions simulating counter-clockwise rotating shifts. The field studies were collaborations with the U.S. Army Aeromedical Research Laboratory (USAARL); testing was conducted at the Miami Air Route Traffic Control Center using FAA air traffic controllers, at USAARL using Army air traffic controllers, and later, in assessing duty-rest issues at Cape May, New Jersey, using volunteer Coast Guard pilots as subjects.

One feature of those studies was an assessment of some ways to counter potential fatigue effects from reduced sleep times, viz., the separate effects of structured napping (20 minutes, 45 minutes, and 2 hours) and of mild exercise. While the latter had no beneficial effects (perhaps the exercise was too mild), napping had some positive consequences. However, the napping also induced "sleep inertia" in some subjects, i.e., a period of grogginess for a while after waking. An appropriate waiting time between waking and working remains to be determined. From the study with FAA controllers, subjective reports indicated that controllers were the most sleepy during the drive home following the midnight shift. Lab and field data indicated that the least sleep occurred prior to the midnight shift.

Congressional interest in controller fatigue led to special funding for the conduct of a shift work and fatigue survey of the controller workforce plus a laboratory study and field research. With input from a scientific panel and an FAA/NATCA (National Air Traffic Controllers Association) work group, CAMI researchers developed an extensive shift work and fatigue survey that was distributed to all controllers in 1999.

The survey effort used a modified version of the Standard Shiftwork Index, an established, comprehensive

survey that encompassed shift work history, sleep and fatigue, health and well-being, social and domestic situation, coping strategies, circadian type, and demographics. The Index was modified by CAMI to incorporate current ATC shift-scheduling practices and to facilitate distribution to the entire ATCS workforce. Feedback to each controller included summary results and a multimedia CD ROM, entitled *Shiftwork Coping Strategies* (10), developed under the guidance of Della Rocco, along with Thomas E. Nesthus, Ph.D., and Crystal Cruz. The CD provided information concerning the effects on fatigue and performance of working a rotating shift schedule and identified ways to improve adaptation and reduce the amount of fatigue associated with working such schedules.

The field study, dubbed the Air Traffic Shiftwork and Fatigue Evaluation (AT-SAFE), was designed to provide empirical data regarding the effects of shift work and shift scheduling on ATCSs and to corroborate the results of the Shiftwork Survey. Data from a Tower/TRACON and an Air Route Traffic Control Center (ARTCC) included: entries into the daily logbooks by the volunteers throughout the 21-day study period (sleep duration, quality of sleep, subjective mood, and sleepiness); measures from wrist activity monitors worn by the volunteers 24 hrs a day to provide corroborative data of sleep duration; and cognitive performance (via CogScreen – Aeromedical Edition).

The laboratory study, headed by Cruz and Nesthus, evaluated clockwise and counter-clockwise rapidly rotating (2-2-1) shift schedules. A direct comparison of the 2 different rotations resulted in reports indicating that the direction of rotation did not affect performance when it came to working the last shift of the week (i.e., the midnight shift). Thus, CAMI's circadian studies have contributed information from both laboratory and field studies, clockwise vs. counter clockwise shift rotations, and effects of scheduled napping and other countermeasures on subjective alertness and measured performance...and provided controllers with coping strategies. □

## An Agency Crisis: Recovery ... And CAMI Shines



### The Strike

In 1981, an historic labor-management and labor law crisis hit the agency – the illegal strike by more than 11,000 air traffic controllers, who were subsequently fired by U.S. President Ronald Reagan. “Strike recovery” imposed immediate, severe, operational requirements (despite curtailment in the amount of traffic) that included the very demanding daily handling of air traffic by a much smaller than needed contingent of controllers supplemented with supervisory and managerial air traffic personnel who went back to the “boards” ... and by some military controllers. It also required major infrastructure changes under intensive time pressures – viz., selecting, training, and hiring thousands of new controllers at a significantly faster pace than ever before while maintaining aviation safety. And CAMI played a key role by increasing its existing partnership with the FAA Academy via the selection and training research psychologists who had succeeded Bart Cobb. One of those researchers, James O. Boone, Ed.D., was recognized as pre-eminent by the FAA Administrator, was assigned to his staff (as FAA-1B), and moved to Washington, D.C., where he participated in the hiring plans and provided statistical projections for decision-making regarding ATC applicants and their training; he later became involved in new agency approaches to management training and ultimately participated in a variety of other high level agency policy groups.

*INTO THE BREACH. Only hours after the air traffic controller strike began, military controllers joined with FAA supervisors, non-striking controllers, and retired controllers who volunteered to return to duty, at air traffic facilities including JFK International (top) and Chicago O’Hare Tower (lower). Ultimately, 850 military controllers participated in maintaining air traffic safety in 13 major cities (46).*





*CONTRIBUTING. Boone (l) leading a strategy session and VanDeventer (r) providing data-based direction to Washington staffers.*

During early 1981, ATCS student loads at the Academy were low. Following the strike, both the Academy – and CAMI – were pressed to respond to greatly increased student inputs and, ultimately for the Academy, a 3/shifts/day training schedule to meet a goal of providing 7,000 Academy graduates to the field by December 1983. Outstanding direct local support on a daily basis was provided by CAMI to the Academy, first by Alan D. VanDeventer, Ph.D., and subsequently by Carol A. Manning, Ph.D. That support included close monitoring of the subjective ratings of Academy laboratory performance, predicting the proportions of ATC applicants who would pass selection tests at various score cut-offs, the proportions that would subsequently pass the Academy pass-fail training, and predicting pass-fail consequences of modifying the curriculum. CAMI quickly established itself as a major contributor by predicting almost exactly the failure rate for the first post-strike classes (for which the immediate need required selecting many candidates from old hiring registers that held a reduced range of qualifying scores).

Another area of psychological contribution by CAMI was related to congressional, other governmental, and press concerns about the potential impact of the new “stress problem” in air traffic control (in the late ‘60s and early ‘70s, the problem was the well-publicized notion of a uniquely stressful nature of the occupation itself and its alleged psychiatric implications – a concern that CAMI’s psychological and physiological research findings helped to dispel). In the context of the extended work hours and work weeks required of controllers for strike recovery, concerns for safety were expressed about fatigue and “burnout.” As a partial response to these concerns, CAMI introduced and conducted stress management lectures at the FAA Academy for all incoming developmental ATCSs from mid-1982 to mid-1986. The lectures were

also video taped by the Air Traffic Service for use at field facilities around the country.

The safety issues and governmental significance of the recovery process, along with concerns for gender and racial fairness, led the Academy to be subjected to additional considerable pressures and scrutiny by congressional as well as agency groups and the media – and the CAMI researchers provided many of the statistical, data-based briefings to those groups. The strike recovery effort was eminently successful and CAMI’s significant contributions received notable recognition.

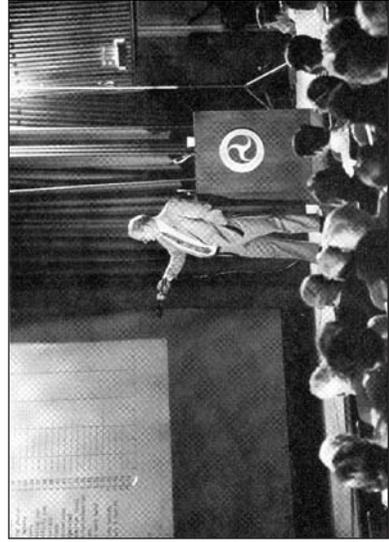
### **Telling It Like It Is**

But that effort was only part of the impact CAMI’s work would have on the FAA and its organization. Investigative groups that looked into the causes of the strike recommended strongly that the agency have better information about its employees, their needs, and their views. In a contracted study of the air traffic control occupation conducted prior to the strike recovery period, the so-called Rose Report had concluded, among other findings, that the ATCS job was not “uniquely stressful” and that what was significant was not so much the job (i.e., controlling traffic) but, rather, the context in which the job was done. Some related findings by the “Jones Committee” (an out-of-agency panel of consulting experts appointed subsequent to the strike) led agency management to look more closely at how management was interacting with its employees.

Thus, in the early spring of 1984, FAA Associate Administrator Charles Weithoner approached William E. Collins, Ph.D., then head of CAMI’s psychology laboratory, for help in developing, administering, and reporting results of an Employee Attitude Survey under conditions of significant time pressure, funding limitations, and organizational tension. The entire agency workforce – then



*AN FAA TURNING POINT. CAMI's start-to-finish role in the first in-depth Employee Attitude Survey of the entire FAA work force began (above) with developmental consultation with Saul B. Sells, Ph.D., (a noted survey specialist) and the sending and receiving of survey forms; scoring and collating (l), reading and coding comments (r); and (below) analyses of data, report preparation, and presentations at Washington Headquarters. The success of that effort was regarded as an "organizational turning point" for the agency.*



47,097 employees - was to be surveyed. The laboratory focus was redirected in support of that goal.

Under David J. Schroeder, Ph.D., a CAMI team (and, on some occasions, the entire laboratory) responded by not only developing, refining, and pre-testing an extensive questionnaire, but also arranging for its printing and mailing through Aeronautical Center services, receiving completed forms, scoring them, analyzing results across a variety of groupings and categories, and preparing final printed reports for the overall agency and for each FAA region independently – with complete confidentiality of respondents and in what the agency lauded as record time. The survey included a comments section and 66 direct ratings of satisfaction with various aspects of the job, the agency and its policies, and various levels of management ... as well as “burnout” – a contentious issue at that time.

In November of 1984, Collins was designated as the scientist to report and interpret the findings to the Administrator and his management team and (during two sessions on the next day) to FAA Washington employees (26). Because of the extraordinary tensions within the agency, those were the first occasions that anyone outside of the CAMI survey team was made aware of any survey result. Later, invited presentations were made to regions (comparing regional and national results) and at national meetings (e.g., of air traffic managers). Also, every employee received a copy of the survey results. While the employee ratings and comments were not all that agency managers had hoped they would be – and some had initial difficulty in accepting the data – the agency developed plans (and updated them with each subsequent survey) to improve aspects of the organization and of work environments based on the results. That included steps to improve “the context” in which the air traffic control and other jobs were done in the agency by establishing an office for an activist associate administrator for human resource management, encouraging employee participation groups, taking other actions designed to improve the work environment and the management of employees (e.g., revamped management training – to which Boone, and later VanDeventer, contributed), and effectively institutionalizing the employee attitude survey.

The confidence of agency management in this CAMI survey product and its interpretation is reflected in the continuation of the survey process approximately bi-annually to date (e.g., 27) - and the continuation of CAMI as the focal point for survey development and analysis. Although made available to all employees in numerous reports, survey data were not published in the OAM series until 2004; Carla Hackworth, Ph.D., now heads that work. For the past decade or more, survey results have been used as one of the agency’s prime indicators of its degree of success in meeting its organizational goals within the Department of Transportation. And that confidence in the performance of CAMI psychologists, from the strike through the recovery, helped lead to the selection of VanDeventer and Deborah Clough, Ph.D., (in addition to Boone) to positions in Washington Headquarters. Moreover, it was a major factor in the encouragement from the agency’s associate administrator level that contributed to making the psychology laboratory a separate research branch (now the Human Factors Research Division) in the Institute. It also stimulated the subsequent recruitment of additional Ph.D. psychologists by Washington offices, most prominently in the area of human resources.

### **Skyjacking and Terrorism**

Significant contributions to other national aviation crises were also made by CAMI and Office of Aviation Medicine psychologists. During the late 1970s, when a worldwide rash of aircraft “skyjackings” occurred, John T. Dailey, Ph.D., at Washington headquarters, was primary in the development of a behavioral profile to assist the airlines in identifying potential hijackers. CAMI’s contribution to the skyjacking issue came when Roger C. Smith, Ph.D., a clinical psychologist, was tapped to provide some of the initial screening, at Fort Dix, New Jersey, for the newly organized Federal Air Marshal Service. Subsequent to the 2001 terrorist attack in New York City, CAMI’s current clinical psychologist, Raymond King, Ph.D., along with Schroeder and Edna Fiedler, Ph.D., were involved during 2002 in the psychological screening of the post-9/11 air marshal applicants, at facilities near Atlantic City, New Jersey. □





## Forensics: Fatal Accidents ... Their Toxicology and Biochemistry



*MAKING A LIVING. Based on their exposure to pesticides, aerial application (crop duster) pilots were a major CARI interest.*

An initial focus of CARI's aviation toxicology laboratory centered on exposure to pesticides and safety concerns for crop duster pilots. Strong support was provided by the aviation physiology laboratory through a number of studies documenting the bodily effects of exposure to those pesticides in major use. Paul W. Smith, Ph.D., original head of the toxicology laboratory, took the lead in defining the hazards of various substances used by such pilots and in promoting guidelines and providing lectures to groups of agricultural pilots.

A later, more enduring research focus was a shift to an emphasis on assessing aircraft cabin and cockpit materials (e.g., panel or seat coverings), for the potential toxic effects of thermal degradation of the materials due to fire. The inhalation toxicity of flame-retardant materials when subjected to fire and heat was an early research thrust led by Charles R. Crane, Ph.D.; with new materials being generated quite regularly, that line of research has continued to date. The subsequent work



by Arvind K. Chaturvedi, Ph.D., and Donald Sanders has involved experiments with recently developed, unique sets of combustion assemblies and exposure chambers to determine the combustion toxicity of the newer polymeric materials now used in some aircraft and of other materials proposed for such use.

### Accident Research

When the small accident research team that went on-site to general aviation accidents from the Protection and Survival Laboratory was moved to the Aviation Toxicology Laboratory, a more direct, wider-scope involvement with fatal accidents began. That involvement came to include participation by William R. Kirkham, M.D., who succeeded Smith as head of the toxicology laboratory and earned from the local media a nickname of "Quincy" (the title character in a popular TV series on medical forensics). At first, accident research teams made trips to general aviation accident sites. Later, the NTSB invited CAMI researchers, such as Stephen J.H. Veronneau, M.D., to participate in some on-site investigations of commercial accidents. CAMI scientists, led by Charles A. DeJohn, M.D., now maintain full records and accounting of major fatal accidents and explore the data to define medical and toxicological areas of potential concern.

CARI/CAMI's toxicology laboratory has long conducted analyses of blood and tissue samples from fatal general aviation accidents; the major early interest was with respect to the involvement of alcohol. Samples were provided from around the country via the well-known

*FIRE AND SMOKE. Crane determined inhalation toxicity of various aircraft cabin materials.*



*GA ACCIDENTS. Early CARI on-site accident research teams participated only in general aviation aircraft accidents.*

CARI/CAMI “tox boxes” provided by the Institute to all Flight Standards District Offices (FSDOs). The FSDO, in addition to a variety of responsibilities including pilot and aircraft certification issues, investigates general aviation accidents and is sometimes assisted by FAA-designated aviation medical examiners (all of whom perform pilot physical examinations and some of whom voluntarily go to local accidents to help obtain data).

### Forensic Quality

CAMI’s current aeromedical research in forensic toxicology runs the gamut from highly technical but pragmatic work under Russell T. Lewis, Ph.D., on analyzing human

blood and tissue samples from fatal aviation accidents for the National Transportation Safety Board (NTSB), to the development of DNA techniques to differentiate ingested alcohol from alcohol that naturally develops from the putrefaction of human tissues, to methodologies for detecting a variety of drugs. CAMI’s continued contracted designation by the NTSB as its primary laboratory for performing state-of-the-art toxicological analyses of fatal aviation accidents (dating from 1986) and of fatal surface accidents (dating from 1998) attests to the quality of the laboratory. That quality is further validated by the laboratory’s successful renewals of accreditations by the American Board of Forensic Toxicology and by the College



*ACCIDENTS AND THE “TOX BOX”. CARI/CAMI’s famous “tox box” kits at Flight Standards District Offices contain instructions and materials to obtain samples from a fatal aircraft accident to be packed and shipped to CAMI for analyses. Precise documentation of all evidence received by CAMI is carried out in a modern accessioning laboratory.*



**Superior Skills...  
Superior Quality**



*NTSB CALLS. During the 1990s CAMI scientists were invited by the NTSB to participate in their accident investigations. Three CAMI employees (Gale Braden in 1976, Mark George, above, in 1998, and Jeffrey Marcus in 1999) have moved from the Institute to positions with the NTSB.*

of American Pathologists – the only laboratory in the world accredited by both organizations. The accreditation program is managed by John W. Soper, Ph.D.

As another means of assuring excellence in quality control, CAMI houses the nation's only proficiency testing program in the field of postmortem forensic toxicology. More than 30 forensic toxicology laboratories around the country regularly participate in this unique CAMI program (initiated and managed by Chaturvedi) that checks the proficiency of analyses of postmortem biological samples.

### **World Class Capability**

The toxicology laboratory was redesigned beginning in 1989 and updated to its present state-of-the-art level by Dennis V. Canfield, Ph.D., culminating in the present major forensic thrust of the (renamed) Bioaeronautical Sciences Research Laboratory. Its world-renowned capabilities in blood and tissue analysis for the NTSB include precision tests for a myriad of drugs as well as alcohol. Blood tests at CAMI can help determine whether aircraft occupants died from an exhaust leak producing carbon monoxide or whether the plane had an in-flight fire prior to crashing. Basic research to improve drug detection and to distinguish, via DNA, ingested alcohol vs. postmortem alcohol has been led by Chaturvedi.

And a more recent investigative initiative involved the formation of a functional genomics team that conducts gene expression research. This team combines analyses of genetic information with computational methods to assess networks of environmentally responsive genes that signal physiological fatigue and performance impairment following exposure to aeromedically significant stressors.



*QUALITY ASSURANCE. Chaturvedi prepares proficiency testing specimens for use both in CAMI's quality assurance programs and for the national program he manages. In 1995, he organized a successful International Colloquium on Advances in Combustion Toxicology hosted at CAMI. The proceedings were published in the journal Toxicology.*

Such stressors include hypoxia, alcohol, drugs, and jet-lag fatigue. Research applications include aeromedical certification as well as post-crash accident investigations.

The laboratory's work not only contributes significantly to NTSB determinations of the causes of (or factors associated with) fatal accidents, but also has sometimes absolved an accused, deceased pilot and, on other occasions, has reduced or eliminated the liability of the agency in complex legal cases. Moreover, CAMI's toxicological analyses also serve as a partial test of the integrity of the aeromedical certification system, specifically with respect to drugs and medical conditions. □



*BUILDING EXCELLENCE. Canfield, architect and head of the Bioaeronautical Sciences Research Laboratory.*