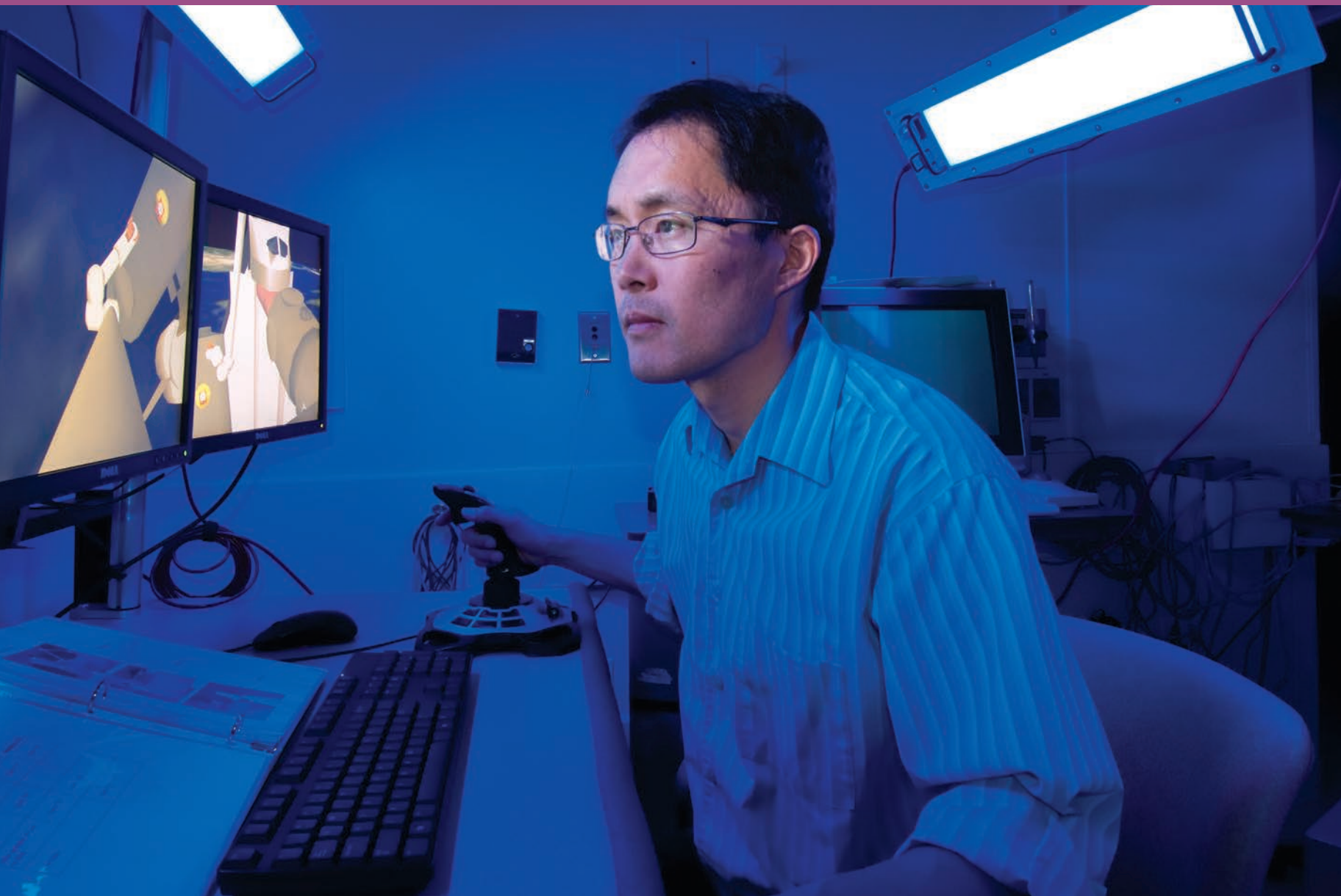
Man Vehicle Lab research scientist Andrew Liu simulates a grappling operation with the same type of hand controllers used to operate the International Space Station's robotic arm. This MVL project examines effects of fatigue resulting from sleep debt, hours awake, and changes in sleep/wake time on performance of a complex task like telerobotics (remote operation of robots) and whether countermeasures such as blue-enriched white light are effective in reducing fatigue. (Andrew Liu)



A HALF-CENTURY OF RESEARCH IN AVIATION, SPACE, AND CLINICAL APPLICATIONS

The Man Vehicle Lab at 50

By Larry Young

Like so many other out of the box innovations in the AeroAstro Department, the ideas that led to the Man Vehicle Lab came from Charles Stark "Doc" Draper.

It was around 1960. Doc had a long-standing interest in the proper roles of man and machine in guidance and control.

Doc, who headed both the MIT Instrumentation Lab and AeroAstro, hired me as an assistant professor in 1962 to introduce the department to what we now call biomedical engineering. He lined me up with Professor Y.T. Li, an amazingly innovative inventor. Together, Li and I jumped on the NASA manned spaceflight bandwagon and began to study humans as biological inertial guidance systems.

We built our first linear acceleration sled in Building 17A (the old blow-down wind tunnel) and thus was born the Man Vehicle Lab, 50 years ago. Our goal since that time has been to better define the physiological and cognitive limitations of the pilots and passengers in airplanes and in spacecraft. We aim to optimize human-vehicle system effectiveness and safety.

To mark the half-century of research in aviation, space, and clinical applications, we and more than 100 alumni and guests celebrated "mvl@50" on September 14, 2012. (Visit http://mvl.mit.edu/MVL-50th.htm to take a look at the celebration videos and pictures of 50 years of the MVL and its alums, including a research memoir, a listing of theses, and of about 900 publications.) Although the "Man" in Man Vehicle is no longer exclusive — many of our students and subjects are women — MVL recognition and reputation are so strong that we retain the name and the perhaps even better known initials.

We've had only three directors over the lab's half century. Initial director Y.T. Li contributed his wisdom, ingenuity, and some of his personal capital, to the earliest decade. He concentrated on mechanically emulating the human balance system for the dynamic stability of narrow-wheelbase vehicles, suitable for the crowded streets of Asia.

Dr. Li passed the directorship to me in 1970, and I handed it to current director Charles Oman in 1992. Chuck developed closer external links to Draper Laboratory, the U.S. Department of Transportation's Volpe Center, and to the vestibular research team at the Massachusetts Eye and Ear Infirmary. Y.T., Chuck, and I were last together at a 2009 MIT Symposium in honor of Chuck's 65th birthday. Dr. Li passed away in 2011 at age 97.

BIOMECHANICS, SPORTS, EXTREME ENVIRONMENTS

It's not surprising that the faculty and many of the students maintain interests in biomechanics in sports and extreme environments. Three of us were varsity alpine skiers in college and four of us are experienced sailors. Oman writes and lectures to ocean sailboat racers on avoiding seasickness. Professor Dava Newman set the women's speed record for a human powered hydrofoil, and spent a sabbatical sailing around the world. Former AeroAstro Professor Steve Bussolari, who's now on the Director's Office Staff at Lincoln Lab, designed the pilot interface for Daedalus, MIT's record-setting man-powered airplane. Former astronaut Jeff Hoffman's space missions included spacewalks to repair the Hubble Space Telescope and to fix a satellite. And, my research on alpine ski bindings contributed to standards that brought the accident rate on the slopes down by a factor of five. We continue to work on head-to toe protective gear — for athletes as well as astronauts.

Astronaut disorientation, space sickness, and deconditioning remain challenges to space exploration and space tourism.

Most of the 200 or so graduate students in the MVL over the past 50 years have applied physiology or psychology to aviation or space. Astronaut disorientation, space sickness, and deconditioning remain challenges to space exploration and space tourism. Disorientation in airplanes and in motion based fight simulators is similarly challenging. Clinical applications to patients suffering from vertigo and

balance disorders provided another avenue for our research. We modeled the physics and neurophysiology of the vestibular system in the inner ear and its connections to muscles. We contributed to understanding posture and balance, as well as the astronaut challenge of walking under the reduced gravity of the Moon and Mars.

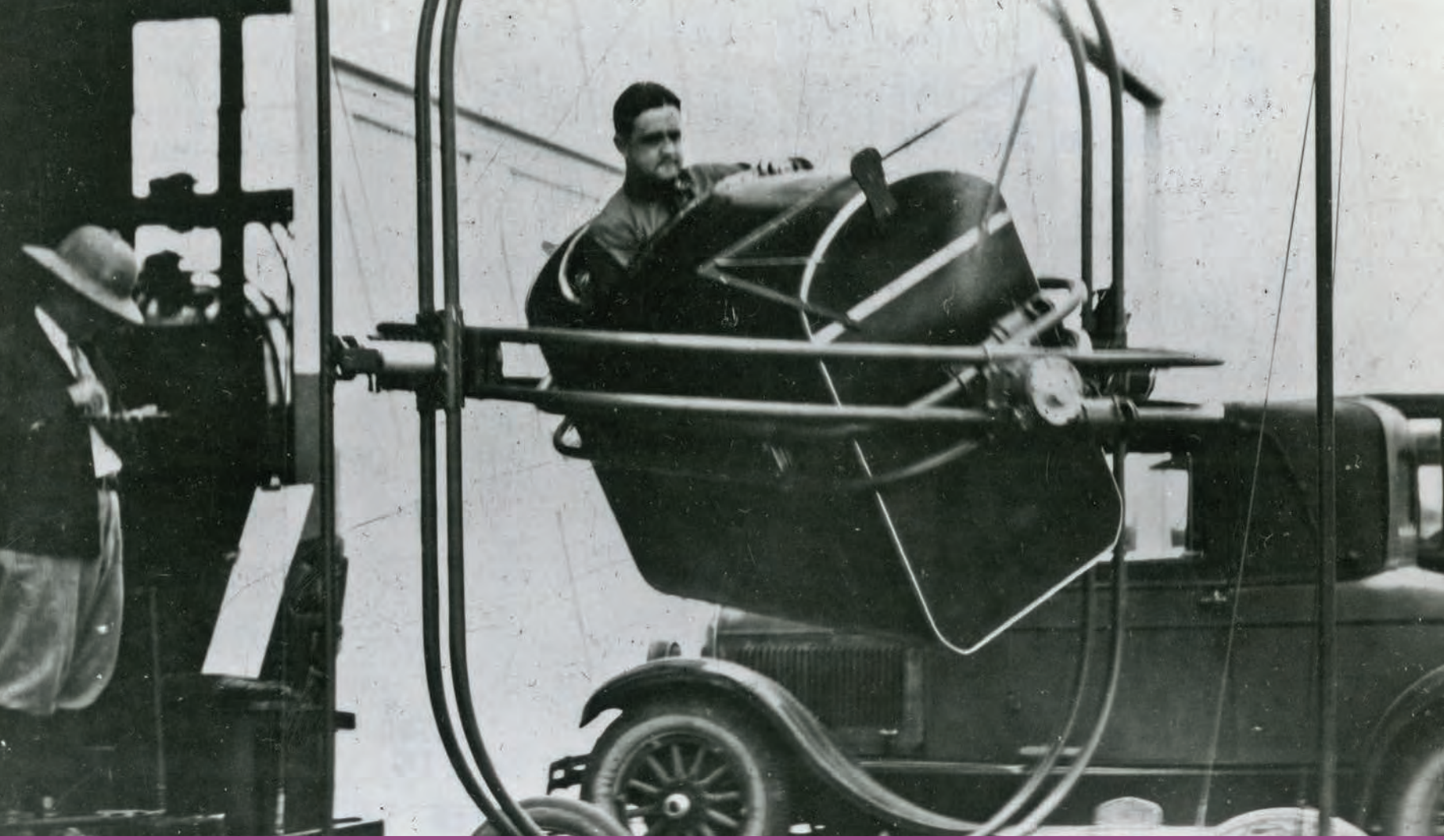
Pictured at a 2009 symposium, the last time they were together, are the three men whose directorships span the 50-year history of the MVL: (from left) current director Charles Oman (1992–), initial director Y.T. Li (1962–1970), and Larry Young (1970–1992). Li passed away in 2011 at age 97.

FLIGHT SIMULATOR REALISM

Whether flight simulators are used for pilot training or for flight research, we want the sensation of motion in a simulator to feel close to that of the real airplane. With that goal in mind, we developed simulator motion-drive algorithms based upon mathematical models of the sensors in the inner ear, and concepts of how the brain blends information from the various senses.

At this time, we are dealing with the disorientation that occurs when a pilot pitches or rolls a vehicle in a gravity field other than that of the Earth — say in lunar (1/6 g) or Martian (3/8 g) gravity — and how it affects the ability to control a descent. We use a large human centrifuge at NASTAR in Pennsylvania to study the related disorientation problem occurring when a pilot, who is in a high-g turn, makes a head movement and feels that the plane has rolled further than it actually has (the "excess-g illusion").

Since human space flight's earliest days, MVL's been involved. For instance, we looked into allowing Apollo astronauts the option of taking over control of the first stage of the Saturn rocket — and decided it was too likely to excite the dangerous bending modes of the rocket. Professors Sandy Alexander, Steve Busollari, and then Dava Newman studied effects of astronaut movement on spacecraft motion, making measurements on the MIR Russian space station. With the introduction of the Space Shuttle and Spacelab, its pressurized laboratory, the MVL became



Doc Draper puts a trainer through its paces at Brooks Field in Texas in 1926. It was Doc's passion for flying and automated guidance and control that led to the creation of the Man Vehicle Lab. (MIT Museum)

a den of "space cadets." We flew major experiments dealing with human balance and orientation on a dozen flights, from the first Spacelab to the last, and learned how gravitational forces are measured and interpreted by the body. We studied how the nervous system reorganizes to adapt to life in weightlessness, as well as how it recovers after return to Earth. Newman, Oman, and I were literally up to our ears in space flight, and our students had the chance to test and train astronauts as well as to try our MIT-built equipment during parabolic flights. It was a blast!

MVL ASTRONAUTS, NASA TIES

Not surprisingly, a number of us wanted to be astronauts, and several succeeded. Byron Lichtenberg became America's first payload specialist, a non-career astronaut brought in for special knowledge of specific payloads. In Byron's case, it was biomedical engineering, and he flew in space twice, helping to establish the desirability of flying technical specialists. Steve Robinson, one of our post-docs who worked on the Spacelab post-flight tests, became a mission specialist who flew four Shuttle missions. Mike Massamino (most recently of "Big Bang Theory" television program notoriety) and Nick Patrick also studied with us, and similarly had successful careers in space. Even I spent two years in training as a payload specialist for a Spacelab mission. As the alternate (or "half-astronaut" as my family irreverently called me), I served as payload communicator rather than going into orbit. Our most experienced astronaut and current faculty colleague is Jeff Hoffman, who returned to MIT following his five Space Shuttle missions and a NASA diplomatic post in Paris. Jeff combines his extensive space flight experience with his science interests to work on space architecture and the planning of exploration missions. TALARIS, his "lunar hopping" concept device to sample numerous sites on the lunar surface, was prototyped by his students and has attracted major interest.

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Dava Newman's long-standing (or more properly, long-walking) research in the biomechanics of extravehicular activity locomotion entailed underwater walking, partial suspension treadmills, and the development of Biosuits — radically different space suits, visually evoking a diver's wetsuit, which do not depend on gas to maintain pressure on the skin.

Our close ties to the space agency extended to frequent faculty and student NASA research tours. At NASA Langley, Chuck Oman, Johannes Dichgans, and I used their large Dual Maneuvering Spheres to quantify visually induced motion (the kind of movement illusion you get when the train on the neighboring track slowly moves away). At NASA Ames we used most of their large motion simulators, including the big outdoor elevator, to test our theories of human motion

For Spacelab's 1983 maiden voyage the MVL prepared experiments to measure changes in astronaut balance. Crew member and MIT/MVL alumnus Byron Lichenberg (SM '75, ScD '79) is shown here during pre-flight acceleration on the lab's "vestibular sled." Instruments inside the box-like helmet measure his eye movements and movement perception. (MVL)

perception, most recently in lunar landing. Dan Merfeld also tested monkey eye movements in their vestibular test lab and Dava Newman built an underwater treadmill to investigate partial gravity locomotion. Extensive astronaut pre-post flight-testing required us to establish labs at the Kennedy Space Center in Florida, at Dryden Flight Research Facility in the high desert of California, and in Houston at the Johnson Space Center. Each time, the MIT students proved their worth to the NASA "pros" and built up a wealth of space experiences to tell their children about.

Like many MIT labs, MVL sprouted successful spinoffs. Lew Nashner turned the posture control platform of his thesis into Neurocom, the world's leading manufacturer of balance platforms and now a division of Natus. Greg Zacharias founded Charles River Analytics to apply pilot modeling to real control problems in aviation. Byron Lichtenberg and Anthony Arrott used their Spacelab experience to found Payload Systems, which is now part of Aurora Flight Sciences. Peter Diamandis, of X-Prize fame, also founded Zero-G, along with Byron, to commercialize parabolic flight.

FACULTY AND VISITING SCHOLARS

Over the years, MVL has been privileged to have a series of dedicated faculty and visiting scholars. Jacob Meiry brought us through the transition from analog to digital and Ren Curry and then Steve Bussolari introduced modern control theory to our simulator motion algorithms. Bob Kenyon showed how modern biomedical instrumentation could be used for our space experiments. Visiting Israeli professors Rafi Sivan and Josh Zeevi left their mark on research and teaching, as did many distinguished international researchers. Outstanding postdocs, too many to mention here, kept the lab running and offered the guidance needed by our students — particularly during the hectic years of our space missions. Our staff members, especially Sherry Modestino and Bob Renshaw, provided the personal and technical glue that kept the whole lab together and created a sense of purpose and community that is still said to be the envy of all.

MVL is turning toward long duration space flight, including artificial gravity (centrifugation) and g-loading suits, to counteract microgravity deconditioning.

To this day, we enjoy the humor and statistical guidance of Alan Natapoff, the human factors expertise of Andy Liu, and the extraordinary administrative talents of Liz Zotos.

As we enter our second half-century, the MVL is turning toward long duration space flight, including artificial gravity (centrifugation) and g-loading suits, to counteract microgravity deconditioning. Virtual reality and artificial intelligence play increasing roles as the interaction of people and machines evolve — and we continue striving to answer Doc Draper's challenge: to use both pilots and computers appropriately, in the air, in space, and now in the clinic.

LARRY YOUNG is the Apollo Program Professor of Astronautics. He is a former director of the Man Vehicle Lab and of the National Space Biomedical Research Institute. He can be reached at lry@mit.edu.