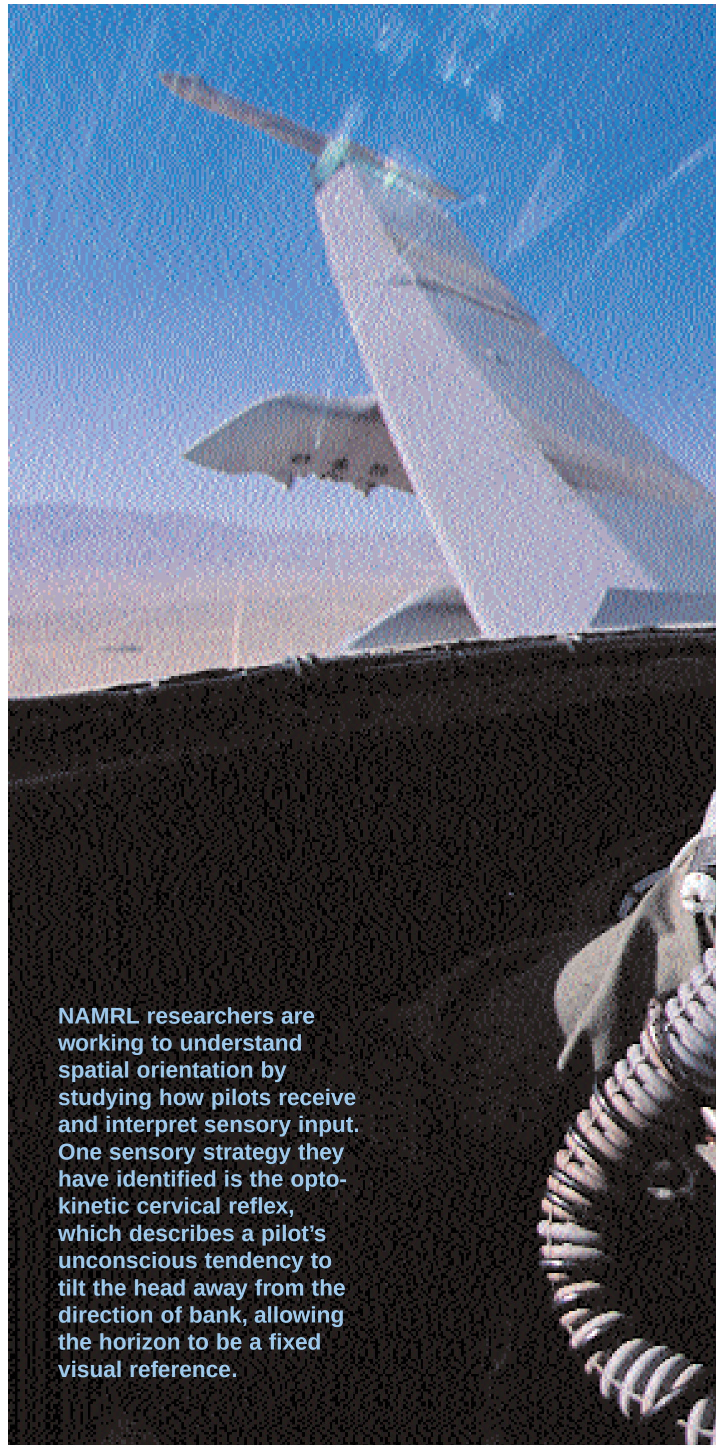
Naval Aerospace Medical Research Lab: Researching the Human Element



NAMRL researchers are working to understand spatial orientation by studying how pilots receive and interpret sensory input. One sensory strategy they have identified is the opto-kinetic cervical reflex, which describes a pilot's unconscious tendency to tilt the head away from the direction of bank, allowing the horizon to be a fixed visual reference.

By Wendy Leland

In the technology-based world of Naval Aviation, both aviator and aircraft are expected to perform at peak levels. But the interface between man and machine is not always a smooth one. An aircraft is not affected by psychology, motion sickness, hearing loss or spatial disorientation, but these are just a few of the factors that can affect the performance of a human within the aircraft. The impact of this mismatch can be enormous. Between 1992 and 1996, 85 percent of all Navy and Marine Corps mishaps took place in the aviation community, and 80 percent of them were attributable to human factors. To improve these figures the human factors must be understood. That's where the Naval Aerospace Medical Research Laboratory (NAMRL), NAS Pensacola, Fla., comes in.

From its roots in the medical department aboard NAS Pensacola in 1939, to its current status as a component command of the Naval Health Research Center, San Diego, Calif., NAMRL has been dedicated to the fleet. The lab conducts dozens of research projects to define and eliminate physiological hazards in operational environments and to set the standards for improving design specifications of aircraft, weapon systems and protective systems. These studies lay the foundation for improving Naval Aviation safety and operational effectiveness.

Sensory Systems

Grampaw Pettibone often rants about particular mishaps that could have been avoided, exclaiming, "Fly your instruments!" He might be surprised to learn that there is an official term for what many of those pilots experienced: spatial disorientation. In certain situations, physical cues may tell pilots they are level when in fact they may be banking, ascending or descending. Without looking at the instruments, they can continue this way until it is too late to correct the error. That's why NAMRL is dedicating many resources to learning how to recognize and combat spatial disorientation.

You may not be familiar with the optokinetic cervical reflex, but if you fly you're most likely putting it to use without realizing it. NAMRL's research shows that pilots reflexively tilt their heads toward the horizon when looking outside the aircraft during roll or

Ted Carlson

pitch maneuvers—even at high Gs or when using night-vision goggles (NVGs). Spatial disorientation can be a consequence of instrument designs that do not accommodate this head-tilt reflex. A pilot looking outside the cockpit focuses on the horizon as the primary visual cue of spatial orientation, while the cockpit is seen in peripheral vision. For example, in a right bank, the pilot moves his or her head to the left to be aligned with the horizon, making the horizon appear stable and the cockpit appear to move. The perceived movement of the cockpit relative to the horizon is to the right, which matches the actual direction of movement.

This picture changes when the pilot switches to instruments. The cockpit now appears stationary and the artificial horizon appears to move so that when right stick is applied, the indicated horizon rotates to the left. At the instant of transition from an outside scan to an inside scan,

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even an experienced pilot may momentarily misinterpret these visual cues and execute a control input that actually has the opposite effect to the intent. In this case, more right stick may be applied to correct a perceived left bank, compounding the actual right bank that is in progress. Similarly, when a pilot's head is tilted while wearing night-vision goggles, the NVG head-up display (HUD) symbology moves with the head so that the visual horizon does not match the display horizon. Sensory mismatches like these can increase a pilot's mental workload and increase the chances of spatial disorientation.

Researchers have been studying how this optokinetic cervical reflex affects the way pilots use current instrumentation. For example, head-up displays are projected on a stationary area approximately 3 by 7 inches, directly in line with the pilot's seat. When the head is tilted not only is the pilot likely to be looking outside the narrow visual range of the HUD, but similar symbols may be easily confused when viewed at an angle. The NAMRL data will provide standards for display symbology and training to improve sensory compatibility with cockpit, head-up and head-mounted displays.

The OZ piloting system, above right, combines the information from several basic flight instruments, above left. Both pilots and nonpilots flying a simulator running OZ were able to maintain a prescribed heading or altitude even under turbulence. Below, the Tactile Situation Awareness System uses the sensation of touch to communicate which way is "down."

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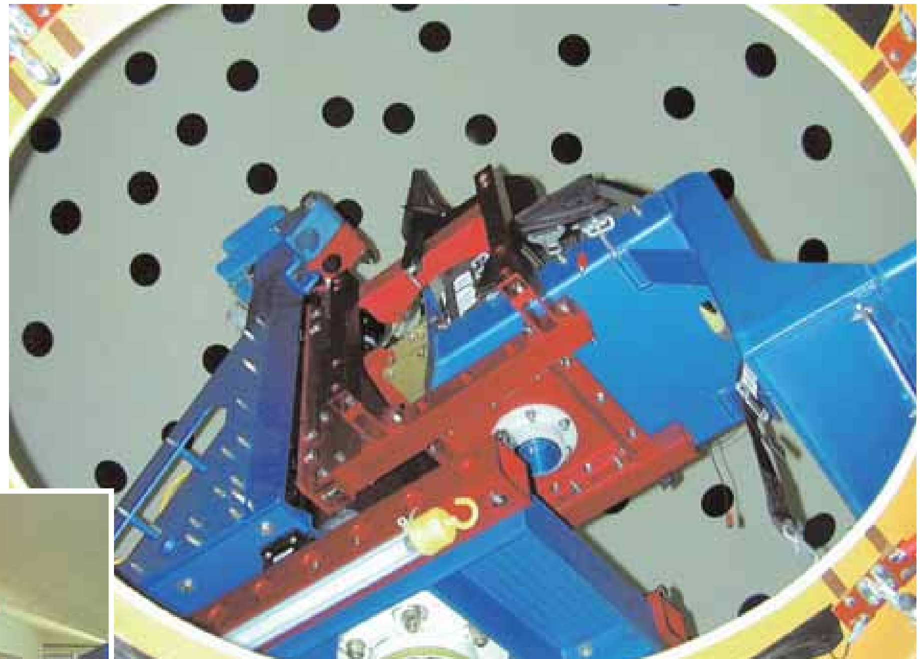
The Tactile Situation Awareness System (TSAS) is another possible answer to the problem of spatial disorientation. The system is a vest laced with a grid of vibrating tactile stimuators, worn close against the body under the flight suit. When any change from level flight occurs, the appropriate tactor begins to vibrate to indicate where the ground is. For example, a 90-degree right bank generates a vibration on the upper right side, indicating it is now pointing toward the ground. A lesser bank vibrates lower on the torso, nose-down is signaled by a vibration on the lower abdomen, and nose-up at the base of the spine. When the aircraft returns to level flight, the TSAS vest is neutral, with no tactile signals. Testing demonstrated that the vest allowed both fixed- and rotary-wing pilots to maintain level flight even when deprived of visual orientation cues.

A concept in development at NAMRL for a combined instrument display may be another way to simplify a pilot's tasks. The piloting system called "OZ" is designed to provide information from several basic instruments in one glance, such as airspeed indicator, artificial horizon, altimeter, compass and turn coordinator.

NAMRL's newest testing device for understanding sensory systems and their impact on pilot performance is the Visual Vestibular Sphere, below. The inside of the sphere is decorated with removable dots, right, so that when it is spun around, the subject seated in the chair experiences the illusion that he or she is moving. Bottom, computerized tests under development at NAMRL may revolutionize the way candidates are screened before entering the aviation pipeline.



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At first glance it looks like an old Atari video game, with a star field of different colored pixels dotted along a black background. But the primitive symbology holds a wealth of information. The screen depicts movement using a grid of dots that narrow down into a vanishing horizon, with horizontal dots for altitude and vertical dots for heading. Flying straight along a heading makes the dots for that heading appear to line up, and deviation makes them appear to separate. Superimposed on the screen is a representation of the aircraft in the form of four symmetrical v-shapes representing the lift-drag ratio, intersected by a vertical line indicating the current power state; a vertical speed indicator; and a compass rose and altitude markers along the screen's edge. A desired speed, altitude or heading can be highlighted on the screen, as well as targets or waypoints. The star field design and redundant wing symbols provide complete information even if up to 80 percent of the display is blocked from view. Exploration of this concept may reveal another weapon in the fight against spatial disorientation.

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Personnel Selection

With the cost to train a single Naval Aviator in excess of $1 million, the financial impact of attrition in the late stages of training is significant. NAMRL's research into creating better selection tests may help reduce attrition by ensuring that only the most qualified students enter the training pipeline.

The Automated Pilot Examination System (APEX) is a computer version of the current Aviation Selection Test Battery (ASTB), which is given about 10,000 times per year to prospective pilots and Naval Flight Officers (NFO) to screen for basic skills. One primary advantage of the computer version is that a change to the test can be immediately and simultaneously available at recruiting offices across the country, whereas a change to the paper-and-pencil ASTB requires that test booklets be recalled, destroyed and replaced with new ones.

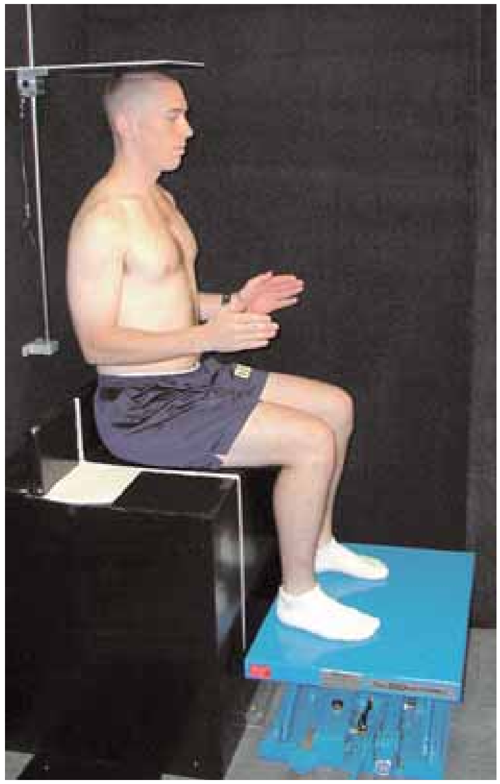
Both versions take about 2.5 hours to complete, but the APEX test is self-paced so the applicant can continue to the next section as desired, rather than wait for the recruiter who is proctoring the ASTB to announce when it is time to move on. Obtaining official results of the ASTB takes approximately two weeks; a recruiter may choose to field-score a test to get results more quickly, but even that takes over an hour. When an APEX test is completed, the data are sent over the internet to a central server, immediately scored, and an email is automatically sent to the recruiter with the results. Since the system first went online in late 1999, five recruiting offices have been administering APEX, demonstrating its validity and ease of use. Following the research and development phase at NAMRL, the system will be brought up to full operational use by the Naval Operational Medical Institute, also at Pensacola.

In collaboration with the Air Force, NAMRL is working on a computerized version of that service's Basic Attributes Test (BAT) to screen for specific physical and mental skills that directly relate to what a pilot or NFO does in the cockpit. For example, a tracking test requires the subject, using a joystick, to keep cross hairs centered on a grid displayed on the computer monitor. During a listening test, the subject hears a series of random letters and numbers simultaneously in both ears and must select only the numbers from a specific ear and input them on the keyboard. By themselves, these tests may not sound difficult, but when run simultaneously they challege both physical and mental coordination and demonstrate the applicant's ability to handle multiple tasks at once. These tests were administered to student aviators who were then tracked through flight training, which showed the tests' ability to predict a student's success. Additional validation came from an unexpected source: when the landing craft air cushion (LCAC) community applied NAMRL's methods to training LCAC craftmasters, the attrition rate was reduced by more than 40 percent.

Research is aimed at selecting other tests for the future BAT, including one to measure how well a person can interpret data on a map in order to navigate a simulated environment, and another to measure the ability to rotate complex three-dimensional objects in space to match a given orientation. A control reversal test can be used to screen potential pilots of unmanned aerial vehicles. This is a challenging task because when the aircraft is flying away from the operator, control inputs have the normal effect—stick moves right, aircraft moves right—but when flying toward the operator, the actions are reversed—stick moves right, aircraft moves left. Psychomotor and cognitive skill tests like these will be a powerful tool in screening potential candidates.

Other personnel selection methods under development include a pilot prediction system (PPS) and a personality test. The PPS will consolidate data from throughout the training command to create a statistical modeling system to predict the person's probability of passing each phase of training. And data gathered from a simple questionnaire given to students during Aviation Preflight Indoctrination will help researchers determine how personality traits affect performance. NAMRL's efforts to devise new testing methods and enhance traditional ones will help ensure that only the most qualified selectees enter the lengthy and expensive aviation training

Jack Saxton



The Digital Anthropometric Video Imaging Device captures digital images of an aviation candidate in prescribed poses, above. Both the images and the physical measurements taken from them are stored in a database for future reference. Below, student aviators pore over a personality test designed by NAMRL.

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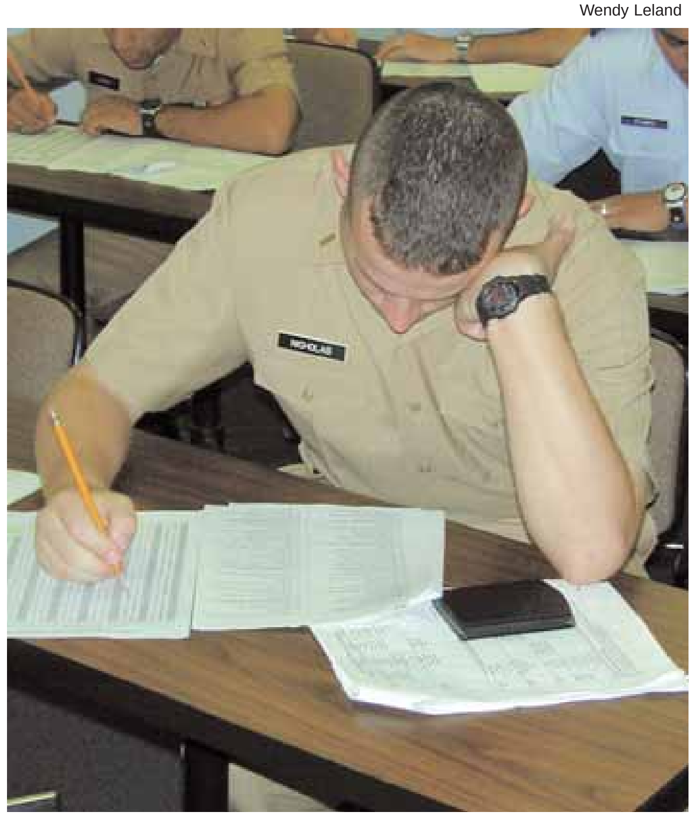

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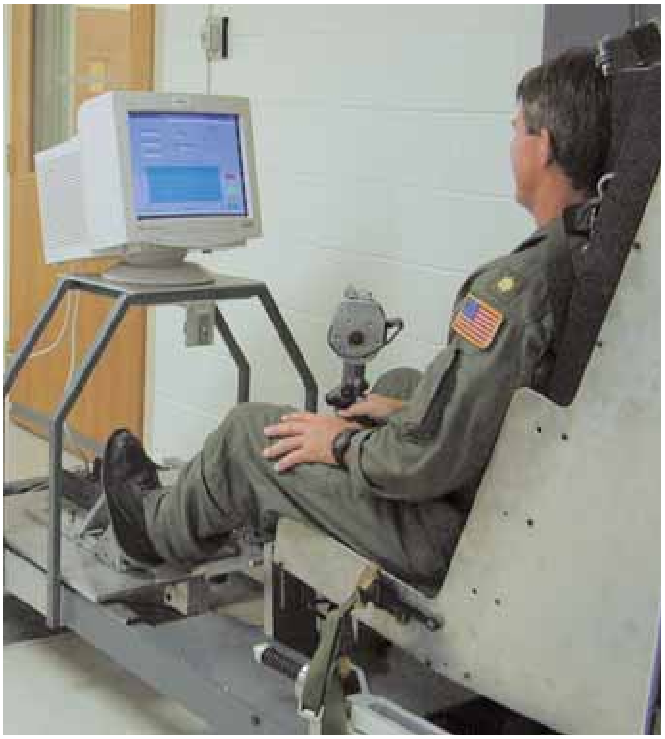

Left, a specially designed device tests a subject's ability to apply sufficient pedal and stick force.

pipeline.

Ergonomics

The digital anthropometric video imaging device (DAVID) is a simple system that could revolutionize a necessary but tedious aspect of Naval Aviation: recording physical measurements of aviation candidates to ensure they meet established criteria. Detailed physical measurements, such as arm or leg length or seated height, help determine what platform an aviator may or may not be able to fly. The current system in use since 1964 requires that each prospective Naval Aviator be measured by hand. Data gathered cannot be checked or reinterpreted at a later date. Additionally, if a question arises about an aviator's ability to fit into a given airframe, the subject must be remeasured or a dynamic fit check performed. This check involves the candidate being test-fitted into an actual aircraft, which can be difficult and time-consuming to arrange.

DAVID seeks to change that. The system records a digital image of the subject in a set of established poses, which are then saved on a computer. An operator marks the endpoints for each measurement on the digital images, the computer calculates the distance, and both the image and the resulting measurements are recorded in a database. If a measurement needs to be confirmed or a new measurement taken at a future date, another operator can call up the image and double-check the placement of the endpoints, rather than requiring that the subject return to be remeasured. Data can be referenced if needed for mishap investigations or for any other reason. The database can also be used to design flight clothing, survival gear, ejection seats and cockpits that better fit a wide range of body types.

Noise Reduction

With noise levels on a flight deck regularly exceeding 145 decibels, hearing loss is another serious issue for Naval Aviation personnel. NAMRL has patented a technology to create improved low-frequency, sound-blocking materials that may be used for aircrew helmets, cranials or sound-deadening materials for stateroom or engine room walls aboard ship.

Physical Conditioning

When wrestling a 15-ton aircraft around the sky, physical conditioning is a must. NAMRL is studying the relationship between physical strength and the ability to perform specific tasks in extreme flight situations. A simulator measuring how much force is produced during stick and pedal movement generates data that can be applied to develop a strength training program for prospective or current aviator trainees.

Testing to determine the effect of reduced exposure to G forces on a Naval Aviator's performance is also underway. With no published information on how G tolerance is built or maintained, NAMRL is attempting to define how much time can pass before deterioration of G tolerance occurs, setting the stage for future guidelines.

Hypoxia Training

Researchers at NAMRL have developed a device to produce hypoxia with less risk than the current altitude chamber training. Rather than physically exposing a subject to lower total pressure in the chamber, subjects may be tested on the ground using a system that changes the composition of a gas mixture that is inhaled through a standard aviation face mask. The system can be used in combination with a simulator to enhance the realism of hypoxia training.

These are just a few of the many research programs underway at this unique facility. But regardless of a program's focus, the final goal of all of NAMRL's projects is the same: to enhance the health and safety of Naval Aviation's most valuable resource—our people.

For further information, call 850-452-3287, x1139, DSN prefix 922.

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