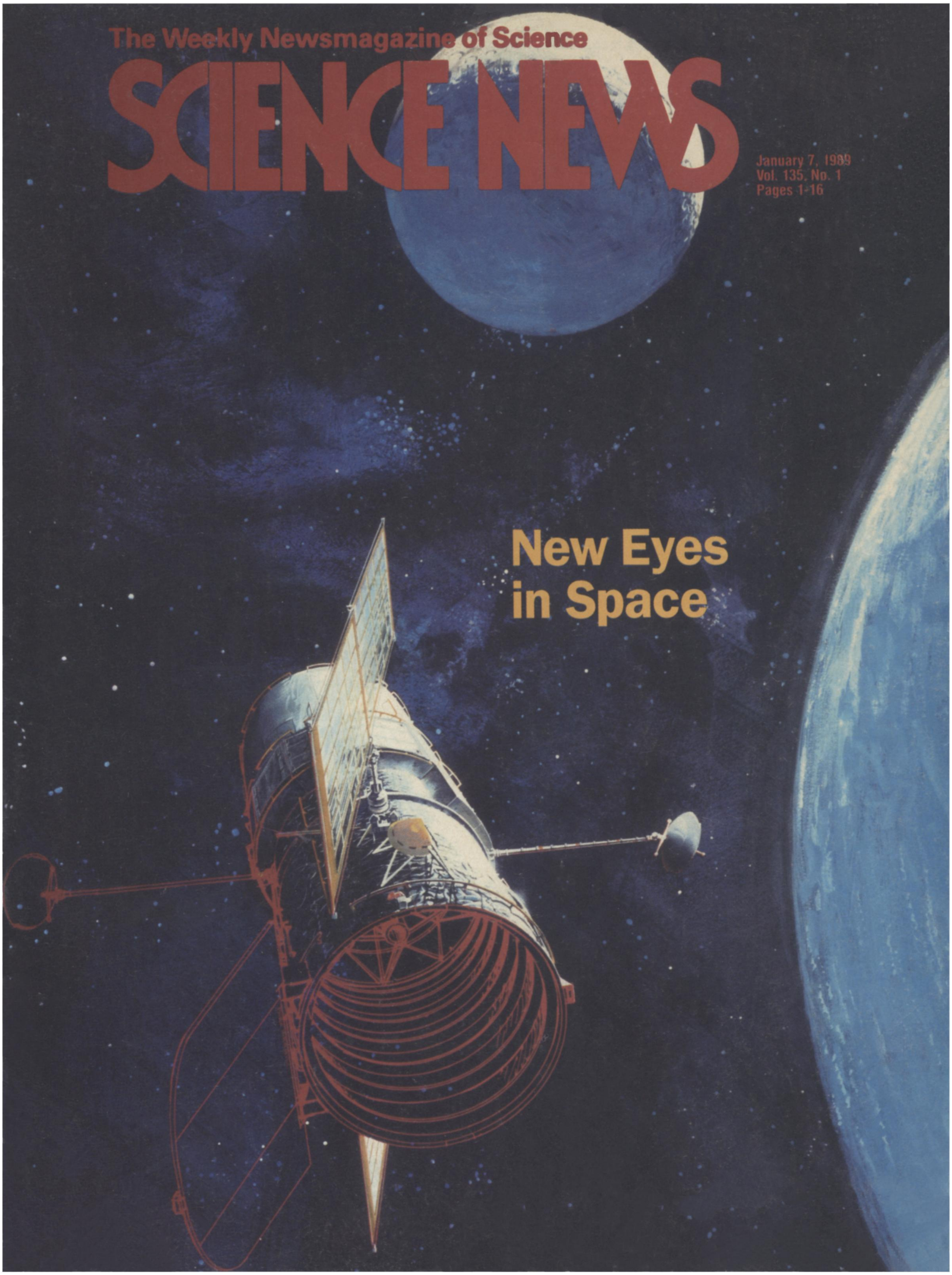
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New Eyes in Space

The Viscous Criterion

Two scientists at the General Motors Research Laboratories have developed a way to predict the probability and severity of impact injuries in the body's soft tissues, including the heart, liver, and the central nervous system. It is an essential step in designing safety systems to reduce such injuries.

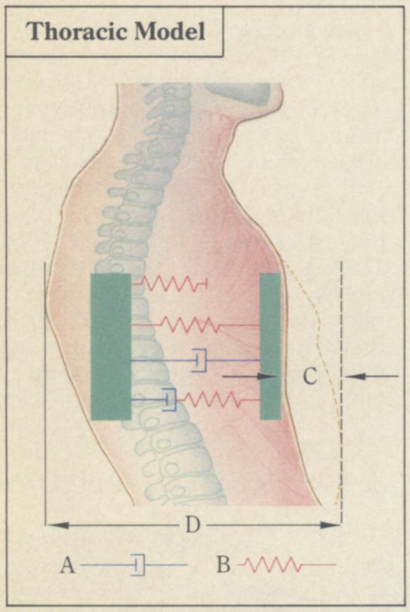
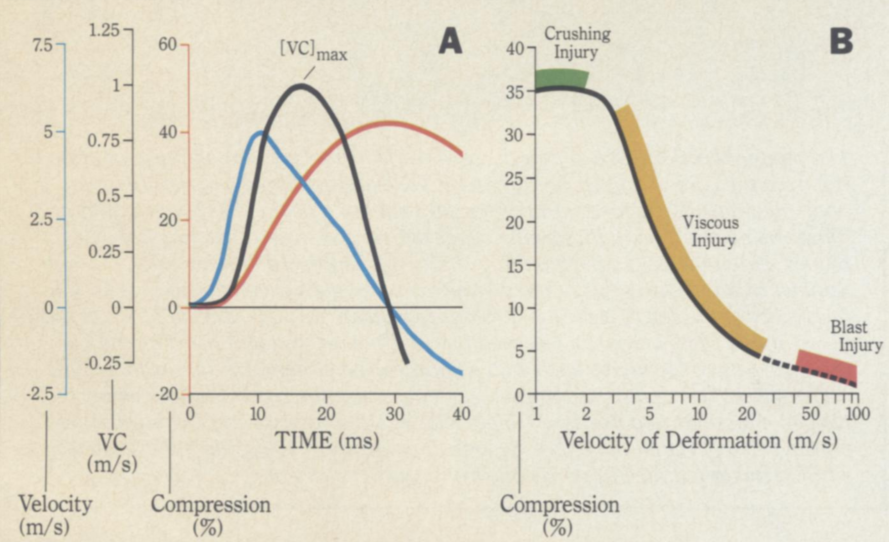


FIGURE 2: Lateral view of a viscoelastic model of the human chest. Dashpot elements (a) and spring elements (b) represent thoracic compliance. Compression (C) is expressed as a percentage of original chest depth (D).

FIGURE 1: A) Plot of viscous response, VC(t), during impact (black). C(t)=normalized compression (red). V(t)=rate of chest deflection (blue). $[VC]_{max}$ defines the Viscous Criterion. B) Range of validity for Viscous Criterion (yellow).



Designing an automobile to reduce the risk of injury to its occupants in a collision demands an ability to correlate the forces generated by the crash with the biological effects experienced by the people involved.

Military rocket sled experiments in the late 1950s measured man's ability to withstand sudden changes in speed. The resulting Acceleration Criterion was used in setting 60g (60 times the force of gravity) as the maximum spinal acceleration allowable under federal motor vehicle standards in a 30 mph crash test.

This Acceleration Criterion treats the body as a rigid structure. Over the years, however, subsequent research on injury mechanisms indicates that injury criteria based on whole-body acceleration are incomplete predictors of injury risk.

The body is a deformable structure, and injury can be sustained when the chest is compressed in an accident. At low speeds of deformation (less than 3 meters per second), the tolerance to rib cage damage and the risk of injury correlate closely to the maximum compression of the chest—expressed as a percentage of the original chest depth from sternum to spine. This Compression Criterion, developed in the early '80s by GM researchers in conjunction with the University of California at San Diego, is useful in evaluating injury risk for safety-belted occupants, where tight coupling to vehicle deceleration reduces the amount of chest compression in a collision.

Doctors Ian Lau and David Viano—both members of the Biomedical Science Department of the General Motors Research Laboratories—began in 1981 to evaluate the importance of velocity in assessing the risk of impact injury. They were concerned that the maximum compression tolerance might underestimate chest injury risk at high speeds of chest deformation (greater than 3 m/s)—typical of unrestrained occupants in a frontal crash, or in high-speed side impacts.

The two scientists designed a series of experiments that held maximum compression constant at 16%—well below the tolerance level of 35%—and varied the rate of abdominal compression from 5 m/s to 20 m/s. The experiments verified that severity of soft tissue injury increased as the velocity of compression increased.

These results, plus further analysis of previous experiments, led Viano and Lau to develop a function called the *Viscous Response* to describe the behavior of soft tissue during an impact event. Viscous Response was defined as the instantaneous product of the velocity of deformation and compression, varying over time: VC(t) (Figure 1A).

The mathematical form of the Viscous Response is derived from analysis of a mechanical analog of the viscoelastic response of the human thorax. (Figure 2). The dashpots (2a) represent the behavior of viscous soft tissue, while the springs (2b) correspond to the elastic skeletal response to impact.

In computing impact energy absorbed by the analog, the dominant term is the product of velocity of deformation and compression, with compression defined as chest deflection normalized by the original chest depth, (Fig. 2, D). Therefore, the Viscous Response is related to absorbed energy.

Drs. Viano and Lau suspected that the injury mechanism for soft tissue was also related to absorbed energy, and designed further experiments to verify the predictive abilities of the peak Viscous Response (VC_{max}). In these tests, velocities of deformation ranged from 5 m/s to 22 m/s and maximum chest compressions ranged from 4% to 55%. Analysis of the test data showed that the maximum Viscous Response was an accurate predictor of injury risk for the entire data set. In addition, VC_{max} was the only biomechanical response that adequately defined injury risk for the full range of test conditions, including the extremes of only 4% compression at 22 m/s, as well as 55% compression at only 5 m/s.

Investigation across this range of deformation velocities effectively links together existing knowledge of crushing injuries, high-speed impact injuries, and data available on blast injuries (Figure 1B).

Applying the Viscous Criterion to previously published blunt frontal impact data, Lau and Viano used statistical analysis to show that VC_{max} was highly correlated with the risk of severe injury. "For velocities of chest deformation above 3.0 m/s," says Dave Viano, "VC_{max} is the principal indicator of injury, whereas for very slow speeds of deflection, the Compression Criterion assesses crushing injury risk. We are, therefore, recommending a viscous tolerance for the chest of VC_{max} equal to 1.00 m/s, and a compression tolerance of C_{max} equal to 35% to minimize the risk of severe injury in an accident."

Ian Lau points out the importance of such risk assessments as targets for automotive designers. "Based on our new awareness of the mechanism of soft tissue injury, General Motors has already designed a self-aligning steering wheel that can be an excellent countermeasure for reducing abdominal injuries in a crash."

The new wheel works in concert with the energy-absorbing steering column, and is available as standard equipment on the 1989 Chevrolet Cavalier. Says Lau, "This is an excellent example of engineering and medical science working together. And because GM is the only auto maker with a biomedical research facility and a dedicated staff of research professionals, it can only happen here."

General Motors

MARK OF EXCELLENCE

THE MEN BEHIND THE WORK:

David C. Viano and Ian V. Lau are both members of the Biomedical Science Department at the GM Research Laboratories.

Dr. Viano (right) is a Principal Research Scientist, leading the department's Safety Research Program. Dave received his BS in Electrical Engineering from the University of Santa Clara; he holds both an MS and a Ph.D. in Applied Mechanics from the California Institute of Technology. Dr. Viano joined GM in 1974 following postdoctoral work in Biomechanics at the Swiss Institute of Technology. His interests include technologies to improve occupant protection, the biomechanics of trauma and disability, transportation safety, and public health approaches to injury control.

Dr. Ian Lau came to the Research Laboratories in 1978, and is now a Senior Staff Research Engineer. Ian has a BS in Electrical Engineering from Lowell University. He holds a Ph.D. in Biomedical Engineering from the School of Medicine of the Johns Hopkins University. Ian was also a Postdoctoral Fellow of the American Heart Association at the Hopkins School of Hygiene and Public Health. His other research interests include traumatic cardiac arrhythmias, and occupant interaction with the steering and supplemental restraint systems.

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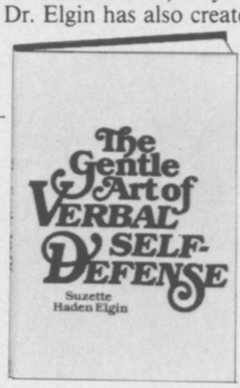
The Gentle Art of Verbal Self-Defense, originally $12.95, now costs only $6.95. And, should you want to return the book, you can do so and have your money refunded with no questions asked.

About the Author

Psycholinguist Suzette Haden Elgin has presented her innovative self-defense principles in a variety of formats. She has given workshops and seminars all over the U.S., including verbal self-defense sessions for doctors, lawyers, and other professionals. Dr. Elgin has also created a self-defense tape and a training manual for people who teach her self-defense techniques.



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