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Occupant Kinematics: A Historical Perspective

Stapp Car Crash Conferences have been conducted annually for quite some years. Each conference features speakers and research on the human aspects of (primarily) motor-vehicle collisions, including occupant kinematics and biomechanics. Occupant kinematics is the study of the motions of persons within vehicles during a collision; biomechanics is a complex field which includes the concept of injury causation and the ability of portions of the anatomy to resist failure or other injury. These conferences are named after Dr. John Paul Stapp

According to the John Paul Stapp Memorial Lecture by Richard F. Chandler, published in Volume 45 of the *Stapp Car Crash Journal*, SAE, Warrendale, PA, 2001, **Project MX-981, Effects of Deceleration Forces of High Magnitude on Man**, was initiated by the U. S. Army Air Force in 1945 to be conducted at its Aero Medical Laboratory at Wright Field, Ohio, to confirm the feasibility of a 40 g crash restraint system for pilots of military aircraft. One g is the acceleration of gravity, 32.2 feet per second per second. It is this acceleration that gives objects on earth weight. At an acceleration of 40 g's, an object which weighs 100 pounds at one g will weigh 4000 pounds.

Captain John Paul Stapp, M.D., was selected to carry out this work. It was subsequently moved to Edwards Air Force Base, California, then to Holloman Air Force Base, New Mexico. Studies at various locations involved human volunteers and chimpanzees, strapped into rail-guided, rocket-powered sleds which were very quickly accelerated to high velocities, then rapidly decelerated to a full stop at rates of deceleration which often exceeded 40 g's. Captain Stapp was often the first human volunteer to attempt a particularly high rate of acceleration. Despite numerous tests during which he was exposed to very high rates of deceleration, his only injuries were several wrist fractures, related to handholds included as part of the test sleds, and a hemorrhage in the retina of the right eye during Run Number 215, causing a black blot in his vision which persisted for ten weeks before gradually clearing. His work and efforts became known to the general public, leading to appearances in magazines and on television, after which he was "retired" to supervisory positions until his retirement in 1970. He continued his involvement in this research, however, by leading the annual Stapp Car Crash Conferences until his death in 1999.

Although this research was funded to determine the feasibility of improved restraint and ejection systems for pilots of military aircraft, many of whom are now alive due to improvements in those systems, the rising tide of fatalities in motor-vehicle collisions gave rise to the now-obvious conclusion that serious injuries and fatalities in such collisions could be mitigated or eliminated by applying the results of these studies to occupants of motor vehicles. Often, the injuries to persons in cars involved in collisions occur as a result of what is commonly called the second impact, the one involving those persons and interior components of the car. During a collision, the center of mass of a motor vehicle may experience decelerations of 20 g's or more, and the duration of the crash pulse is often only 0.10 second. The car stops or is very rapidly decelerated, but the unrestrained occupants continue to move at whatever speed the car was traveling before impact, striking interior components and causing localized applications of very high forces leading to serious and/or fatal injuries. Bones break, organs and/or arteries burst, and people are maimed, disabled, or killed. The application of the observation that the human body can safely experience very high rates of deceleration if it is uniformly dispersed over the anatomy led to one of the first safety improvements required in cars: the seat belt.

Before collapsing steering columns, many drivers in head-on collisions were killed when the steering column was pushed into (and sometimes through) the chest. Collapsing steering columns were mandated in cars and have been standard equipment in them for many decades, eliminating that injury mode as a cause of collision-induced death in car crashes.

After some years of experience with lap-only belts, it became obvious that restraining the lower torso allowed the upper torso of a driver to pivot into the steering wheel, which impact often caused disfiguring (and sometimes fatal) injuries. Use of a five-point restraint system in vehicles for the general public was deemed unfeasible, but the now-common three-point system was developed and incorporated. At first, many manufacturers

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