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Toyota Motor Corporation

TOTAL HUMAN MODEL FOR SAFETY (THUMS): REVOLUTIONIZING CRASH SIMULATION TO SUPPORT SAFE MOBILITY FOR ALL

Used around the world by researchers and engineers, Toyota's Total Human Model for Safety (THUMS) is one of the most advanced systems available to simulate and analyze injuries caused in motor vehicle collisions. Made available for free in January 2021, the system is the culmination of more than twenty years work driven by Toyota's longstanding pursuit of a safe mobility society.

Understanding THUMS

Beginning in the 1980s, automakers began to explore the potential for computers to simulate vehicle collisions. While physical dummies had been used for decades, virtual simulations offered new opportunities to reproduce and analyze exactly how a vehicle body deforms as it absorbs the energy from a collision.

In the 1990s, Toyota Motor Corporation (Toyota) and Toyota Central R&D Labs began to collaborate on extending this simulation technology to the human occupants of a vehicle, developing a virtual model that could be used to simulate and calculate damage to the human body in a vehicle collisions. In 2000, they launched Total Human Model for Safety (THUMS), the first virtual human body model software in the world that could simulate the entire body. Today, that first generation has been extended to become one of the most advanced such virtual models in the world, distinguished by its great precision in representing not just the structures of the body, including bones, organs, muscles and more, but also their durability in response to force and impact. It has also expanded its capabilities to include virtual models of all ages and genders, ensuring that human diversity is built into auto safety from the beginning of the engineering process.

Today, just as in 2000, THUMS is more than a piece of software. Instead, it represents a revolution in vehicle safety testing, helping to empower a human-centric focus that is designed to make cities, communities and infrastructure more sustainable by protecting the health and well-being of people.

The Development Process

Collision simulation technology is thought to have begun in the 1950s to support military aviation research in the United States. It expanded to the auto industry as carmakers looked for less expensive, repeatable ways to test vehicle designs throughout the development process.

By the 1990s, automakers were also looking for ways to push beyond traditional physical crash test dummies. Japanese automakers, including Toyota, began to send engineers to Wayne State University in

Detroit, Michigan to study biomechanics and research injury to the human body.

Yuichi Kitagawa, who today leads THUMS development at Toyota, was one of them. He remembers that, “we carried out research using donated corpses to find out how much load the human body can withstand. Having an understanding of the human body is crucial to developing the virtual human body model and in order to develop a truly safe car, research that reproduces a fragile human body is key.”

This kind of study was well outside of the norm for automotive engineers at the time, but as Kitagawa added, “though it took some time to get used to, I believe this was necessary to understand the human body.”

Armed with this research, Toyota engineers began to manually design three-dimensional meshes that would reproduce the shapes of the human body, and to program the mechanical properties for its component parts, including bones and internal organs. When finished, they had not only completed the first virtual human body model to offer a precise reproduction of the entire human body, but also developed a simulation tool that could go above and beyond what was possible with vehicle collision tests.

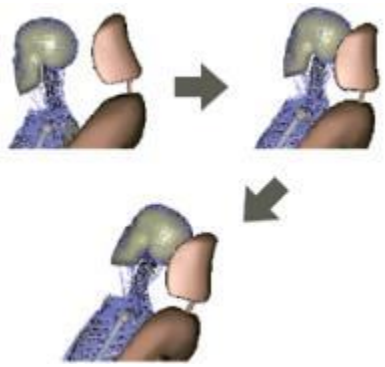
THUMS Version One launched in 2000

Because physical crash dummies are designed to withstand multiple tests, they are limited in how accurately they can represent a human body. Because it is virtual, THUMS models can much more accurately therefore evaluate the potential injuries in more detail. What’s more, THUMS has the advantage of repeatability of its testing capabilities as it can perform thousands of different analyses of a collision by making small changes to the conditions of the simulation – something that is simply not possible in an actual vehicle crash test.

Putting THUMS to work

Toyota launched THUMS Version One in the year 2000 and has followed with six more versions that evolve and broaden the model’s scope. This includes expanding it to consider different factors, including gender, age, differences in physique, brains, internal organs and muscles.

Over the years, the technology has repeatedly helped to engineer improved systems to protect occupant safety. One of its first uses was to help reduce injuries associated with whiplash, which occurs when a person's head quickly moves backward and then forward, most often following a rear-end collision. But while whiplash injuries are frequently reported after these incidents, the severity of the injury is not directly related to the scale of the collision or damage to the vehicle itself. After THUMS was able to successfully reproduce the same conditions seen in human test studies, the system was used to repeatedly simulate the placement and movement of the head to help develop a new prototype headrest that is now installed on a range of Toyota vehicles worldwide.

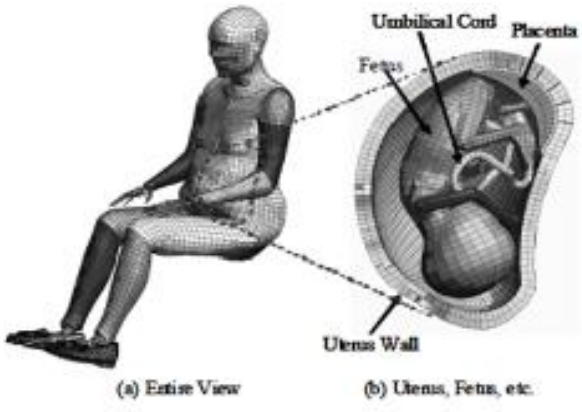


Movement simulation of a rear-end collision using THUMS

Later, as THUMS expanded to include a models of different body types, the system was used to study whether it was safe for pregnant women to wear seatbelts. At the time, some in the industry questioned whether pregnant women should wear them, worrying that the belt would hurt the fetus in a crash.

To answer the question, Kitagawa developed a THUMS model of a pregnant woman, visiting an obstetrics and gynecology hospital, talking to doctors, and reading many technical documents on pregnant women and fetuses. He recalls feeling "uneasy waiting in the obstetrics and gynecology hospital waiting room by myself."

With the help of Toyota Central Lab, Toyota was able to develop a new model that included the uterus, fetus, placenta, umbilical cord and amniotic fluid. Using it, the company simulated two frontal car crashes, one involving a pregnant passenger wearing a seatbelt and the other with a pregnant passenger without a seatbelt. The tests showed that a passenger not wearing a seatbelt would sustain severe injuries after being thrown violently towards the front of the vehicle. By contrast, wearing the seatbelt under the pelvis protected the mother with minimal impact to the uterus and placenta. Toyota presented this research at an automotive academic conference, which led to the revision of traffic rules and a broad acceptance that carrying mothers should wear seatbelts.



Model of pregnant passenger and fetus

Toward a safe mobility society

THUMS was created to help Toyota spur the development improved passive vehicle safety systems, and ultimately to move towards a safe, inclusive, mobile society. Today, the system is used in vehicle safety research by over 100 vehicle manufacturers, suppliers, universities, and research institutions, among others. Looking ahead, the system also holds significant promise in testing vehicle safety for new categories of mobility, including highly-automated vehicles that may have different seating configurations than traditional cars and trucks.

To help support this research, Toyota will make the THUMS software freely available beginning January 2021. By reducing the barriers to the technology, the company hopes to enable even more widespread use, as well as shared learning and research that can spur system development to even higher levels of precision.

This approach follows on Toyota values defined by Sakichi Toyoda, who called on employees to, “always be faithful to your duties, thereby contributing to the company and to the overall good.” THUMS is a key element to Toyota’s pursuit of a sustainable society that supports good health and well-being for all. This includes a vision of a safe mobility society with zero traffic accident casualties and fatalities.