In the Olympics, hundredths of a second can be all that separates a medal performance from no medal at all. When the margin of victory is that small — whether running or rowing, cycling or swimming — elite athletes will look for an advantage that provides a competitive edge. Dedicated training has always been the foundation for a gold medal performance, but with only fractions of a heartbeat separating winners and losers, techniques such as psychology, nutrition, physical therapy, massage and meditation have all become important tools for the Olympic athlete. With athletic performance in many sports approaching the supposed limits of the human body, improved performance will more often come from dimensions other than fitness.

Engineering simulation, a valuable tool in certain high-tech industries for the last three decades and currently growing in its commercial and industrial reach, is now also reaching into the world of sports. High-profile examples — such as the 2007 America’s Cup and the 2007 Formula One racing season — have conclusively demonstrated the effectiveness of computer-aided engineering and the competitive advantage it can provide. In both examples, the winners invested heavily in simulation analysis.

Simulation has also been used in the two most recent Olympic Games — the 2004 Summer Games in Athens, Greece, and the 2006 Winter Games in Turino, Italy — but both its adoption and visibility have been somewhat limited to date. The recent launch of the Speedo racing swimsuit in February of 2008, though, has made quite a splash in the press. The timing of the product launch to coincide with the Olympics, the publicity that the rapidly falling world records has generated, and the subsequent controversy about fairness that the suit has sparked have generated a high level of buzz. The Beijing Games in all likelihood will be a turning point in the marriage of simulation and sport, accelerating its adoption by teams and nations looking to improve medal counts and shining the spotlight on simulation for spectators and the general public. It wouldn’t be surprising if post-event office cooler conversations turn to the simulation color commentary.

While certain individuals in the sporting community have carried the
simulation torch for years, and certain teams and countries have already adopted it wholeheartedly, others are just beginning to experiment. The simulation-enabled medal count in Beijing will likely provide the tipping point. The water sports — where hydrodynamic design and optimized technique can enhance speed — are all prime candidates for further analysis. This includes swimming, of course, but also all of the boating events, such as canoeing, kayaking, rowing and sailing. As with the America’s Cup yacht designs, which have benefited from a significant investment in simulation analysis, every detail of boat design, from the hull to the most inconsequential fixture, can influence performance and benefit from multiphysics analysis. All of the cycling events, with victory dependent on aerodynamic and structural variables — such as helmet shape, wheel design, derailleur materials, and shifter mechanisms — can benefit from fluids and structural analysis. In tennis, racquet design and material choices have already revolutionized the sport, increasing speed, power and control. And even in track and field events, where the equipment is simple — simply shoes in many cases — design and material advances can provide increased bounce, a lengthened stride and the infinitesimal nose that can provide the winning edge in a photo finish.

While simulation is likely to emerge into the public spotlight in this year’s Olympic Games because of its impact on the events themselves, its impact and influence on the design of the event venues — the stadia and sporting centers — will most likely remain out of the public eye. The use of both mechanical and fluids analysis for the design of buildings and the comfort and safety of the spectators, press and athletes who use the buildings is a more traditional and entrenched use of the technology.

2008 Beijing Olympic Results

Swimmers wearing Speedo’s new LZR RACER® suit, designed using ANSYS software, won 94% of the gold medals awarded and set 23 new world records.

The British track cycling team, supported by ANSYS technology, won 13 medals, including 7 golds in a total of 10 events.

With ANSYS simulation-enhanced boat designs, the German flatwater kayaking team won a total of 6 medals.
The National Stadium – Bird’s Nest
The Beijing National Stadium, or Bird’s Nest, is the main stadium for the Beijing games and was designed by Swiss architects Herzog & de Meuron to incorporate universal qualities of beauty and to be sensitive to Chinese cultural traditions. This venue hosted the opening and closing ceremonies as well as the track and field events. The 332 meter long by 296 meter wide elliptical structure has an unusual lattice steel design. One group of researchers simulated the structure using ANSYS software for static and dynamic analysis. Another group used simulation to evaluate the structural response to a spatially varying magnitude 7 earthquake in which there were multiple support excitations and multiple natural frequencies in the 1 to 6 Hz range. In this study, displacements of up to 0.9 meters were predicted and within acceptable limits for the design.

Table Tennis Gymnasium
As one of the most popular sports in China, table tennis warranted a worthy venue. The gymnasium’s roof, incorporating a central transparent ball shape, was designed in keeping with both traditional features and the modern Beijing style. Researchers at Tongji University used ANSYS software for a nonlinear analysis of the pre-stressed, steel truss roof structure. In this analysis, researchers assessed the hybrid tension design for pre-stress, nonlinear buckling and the ultimate bearing capacity of the roof. The engineering group applied BEAM188 elements and took into account geometric, material and support condition nonlinearities caused by the slide bearing. The team determined that the structural validity of the roof depended on the strength and rigidity of the support column, which is comprised of a central rigid ring (5 meter by 2 meter) and roof brace system. The analysis helped in the creation of an optimum design.

Badminton Arena
Badminton — another popular sport in China, like table tennis — was played in an arena designed in the shape of a shuttlecock. The building is a single-layer reticulated shell structure that is 62 meters long by 46 meters wide. Researchers at Beijing University of Technology used ANSYS software to perform a nonlinear stability analysis. The team used BEAM188 elements — a 3-D linear finite beam element, based on the Timoshenko beam theory. The analysis took into account shear deformation and rotational inertia effects. Utilizing ANSYS Parametric Design Language (APDL), the research team constructed a virtual model of the arena. The simulation results indicated that the structure is least stable if the initial geometry disfigurement ratio is approximately 1/250.
Track Cycling – The British National Team
In competitive track cycling, aerodynamic drag is perhaps the most important adversary. Pedaling a single-speed, lightweight racing bicycle on a 250-meter banked oval track requires attention to every detail in order to shave fractions of seconds. The bicycle–rider system, while seemingly simple, contains approximately 250 components — all of them critical when waging a war on drag. Derailleur, sprocket, chain, wheels, helmets and suits can all be optimized, resulting in incremental gains in speed. Working with UK Sport’s Innovation team, the British track cycling team has employed simulation technology supported by TotalSim to a degree that few other Olympic teams have done to date. Following the 2004 Athens Games, in which they won four medals, the team has invested significant resources in research and development, much of it on the computer. The results at the recent World Track Championships in March 2008 had the British team winning nine out of 18 gold medals.

Swimming – The Speedo LZR RACER Swimsuit
From the starting gun to the final touch, there is nothing between an Olympic swimmer and a medal except water. Decreasing passive drag was the engineering challenge that Speedo took on three years ago when it partnered with a number of organizations — including ANSYS, NASA and several universities — to create the world’s fastest swimsuit. In conjunction with research on fabrics and suit construction, as well as testing in water flumes, fluid analysis using ANSYS software was a critical part of the project. With the analysis identifying the locations of greatest drag on the swimmer’s body, special fabric panels were bonded to the suit in those regions and were also used to mold the swimmer into a more hydrodynamic shape. It has been calculated that the suit has five percent less passive drag than their previous fastest suit, and world records have fallen at an unprecedented rate since the introduction of the LZR RACER swimsuit in February 2008.

Flatwater Kayaking – The German National Team
Take a carbon fiber kayak no longer than 5.20 meters and no heavier than 12 kilograms with an accentuated V-shaped hull and very low draft when loaded. Add elite paddlers stroking at racing pace with double-bladed paddles, and you have the ingredients for a very complex simulation problem. The Institut for Research and Development of Sports Equipment (FES) in Berlin performed this fluids analysis calculation using ANSYS CFX software. As the paddles grab the water, the trim of the boat and the water resistance change constantly. The simulation, which involved two-phase flow around the hull and calculation of the boat’s changing trim, were verified through experimentation in a towing tank. The end result was an overall reduction in drag of up to three percent. Using simulation, FES helped design the German team’s entire fleet of flatwater racing kayaks for the Beijing Games, as well as boats for the canoeing, rowing and sailing events.

Thanks to the following for their assistance with this article: for the Speedo swimsuit story: Keith Hanna, Leigh Bramall, Natalie Fieldsend and Helen Rushby, ANSYS UK, Ltd.; for the track cycling story: Rob Lewis, Total Sim; Scott Drawer, UK Sport; Natalie Fieldsend, ANSYS UK, Ltd.; for the flatwater kayaking story: Mathias Jirka, ANSYS Germany GmbH; Nicholas Warzecha, FES Berlin; for the Olympic venue stories: Tony Hu and Angela Liu, ANSYS China (Pera Global Holdings, Inc.).