CSE 415: Introduction to Parallel Computing
Spring 2018, Homework 1
Due 5 pm, Monday, Jan 22nd

This homework is 10% of your ***homework grade*** *(not your total grade).*

Read the "Simulation-Based Engineering for Industrial Competitive Advantage" article (attached) in Computing in Science & Engineering Journal by Loren Miller.

- Write your review and reflections about the article (*about 0.5 pages using single space 11 pt fonts with 1 inch margins, maximum length 0.75 pages*). Your essay should contain discussions on the following:
  - A summary of the Goodyear-Sandia success story,
  - What have been the main contributors to the success of the Goodyear-Sandia partnership?
  - What were the main challenges that were overcome?
  - What is the main message of this story for the US industry and government today?

- Do your own research and explain the following terms:
  - Finite element method, mesh generation, verification and validation, petaflops, exascale computing.

Instructions:

- Submit your homework to by following the "Homework Instructions" document under the "Reference Material" section on D2L. Your submission must be in the form of a pdf document, named HW1-*yourMSUNetID*.pdf.

Simulation-Based Engineering for Industrial Competitive Advantage

Through their simulation-based engineering (SBE) design partnership, Goodyear achieved a substantial competitive advantage in new product development and Sandia National Laboratories was able to solve previously intractable nuclear weapons design problems. However, while other governments invest heavily in SBE for global competitiveness, the US has eliminated technical-transfer funding that was critical to establishing the Goodyear-Sandia partnership.

January in Akron, Ohio is often cold and snowy. In 1986, it was unusually so. For the 30 Goodyear associates meeting in a hotel south of town, the cold weather ensured few distractions from the objective: creating an automated process to speed the production of prototype tires. Although Goodyear made many manufacturing process improvements to improve prototype tire production, associates from Akron, Brussels, and Luxembourg representing product development, specification systems, information technology, and corporate project management were sequestered in a conference room for two weeks to consider a more radical change—an automated system to create the product drawings and material information that would form the engineering definition of their products.

The meetings were anything but pacific. While the weather outside was cold and blustery, the participants vigorously, sometimes heatedly, represented the groups that designed the product, translated and inserted the product information into computer databases, and distributed that information to the production plants. Nearly everyone saw their own process or computer system as central to the solution and the others as tangential. Nevertheless, by the end of the two weeks of discussion and argument, the team had conceived and proposed an audacious solution: the Experimental Parametric Design System.

EPDS was a radical concept. In 1986, engineering workstations were relatively new tools from companies like IBM and Sun Microsystems. Commercial computer-aided design systems were electronic drafting tools, and parametric systems didn't yet exist commercially. Further complicating matters, Goodyear was engaged in a fight for its existence. Sir James Goldsmith, the British financier and corporate raider, was in the process of attempting to gain control of the company and strip it of its assets. Despite the financial headwinds, the disparate group of associates went back to their management teams and sold the concept to the chief operating officer as the only feasible way to dramatically reduce prototype production time. A million dollars was fought over and allocated, the project team was selected, and the EPDS project began.

Although no one realized it then, just a few years later these efforts would become a key enabler for another, even bigger project—instituting simulation-based engineering (SBE) design.

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Background: Goodyear's Financial Challenge

By 1992, Goodyear had weathered a takeover, but at a significant price. The expense of blocking the takeover had forced the sales of an underperforming asset, an oil pipeline, and a cherished source of high technology, Goodyear Aerospace. (Goodyear Aerospace was a pioneer in the commercial production of single instruction, multiple data [SIMD] parallel computers for use in military airborne warning and control systems [AWACS].) The COO had become CEO and retired. Debts were high and the company was focused on internal cost reductions to service the debt. EPDS was a reality, but the new corporate challenge was to dramatically reduce the overall cost of developing new products.

Goodyear had been in existence for almost 100 years. Its product development process was careful and conservative—ever mindful that the braking, cornering, and accelerating forces on vehicles are all transmitted through tire and road contact patches, which for passenger car tires, are each about the size of the palm of your hand. The corporate motto was "Protect Our Good Name." Goodyear associates were dedicated to ensuring their products' performance and integrity using prototype tires and evaluation techniques developed over the company's history.

Goodyear's competitors were now other multinational corporations, principally Michelin in France and Bridgestone in Japan. Foreign competitors had purchased the company's domestic competitors, including Firestone, Goodrich, General, Uniroyal, and Armstrong, several of whom had been headquartered just across town. Goodyear and Cooper were the last of the US domestic tire industry, and only Goodyear was a player in the original equipment market. Goodyear's foreign competitors were better financed, not having been raided, and were outspending Goodyear in product development. The company couldn't match them dollar for dollar because of its debt.

Cost-Reduction Strategies

At the vice president of product development's request, a small team was assembled to consider how to reduce development costs. Three alternative strategies emerged. The first was to continue to improve the existing development processes by building and testing prototypes more quickly and at lower cost. The second was to develop and deploy more predictive laboratory tests as substitutes for road and track tests. The third was to switch paradigms and perform product tests on the computer using SBE design.

Although many associates preferred to develop tires in the traditional way, it soon became apparent that prototype tire building and testing was an "industrial arms race" that Goodyear, due to its financial situation, would be unable to win. Nevertheless, the respective process owners were tasked to do what they could to reduce costs.

Upon analysis, the team determined that predictive testing was key to developing more in-depth product knowledge. The company redoubled its efforts to create laboratory tests to predict full vehicle tests. It seemed unlikely that all product development needs could be met in that manner, however. Furthermore, predictive testing required the production of either prototype tires or carefully assembled test specimens at significant costs in time and money. A predictive testing organization was created to see what could be accomplished.

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Simulation-Based Design Solution

SBE design, like EPDS several years before, was the radical solution. The state-of-the-art was discouraging. Finite-element analysis was the province of bright, highly educated analysts who were willing to create models by hand using crude tools and wait—in some cases for months—to get results that generally lacked enough detail to capture the "true physics of the problem."

There were positives, however. EPDS could provide a product definition with all component geometries and materials. An internal research group had developed an analysis code to roll simple tire models and was in discussions with a national laboratory regarding other code options. Most important, however, compute power was following Moore's law and was the only resource under consideration that promised to become more capable over time at significantly lower cost.

Only later would it become clear that the key competitive advantage of SBE design wasn't cost reduction, but time-to-market reduction.

Sandia National Laboratories

While the Goodyear team focused on defining various alternatives to prototype building and testing, a small group of researchers was becoming increasingly excited about an unexpected contact with one of the Department of Energy's nuclear weapons laboratories, Sandia National Laboratories. The contact had begun a bit whimsically in response to a Sandia technology-transfer newsletter offering help to US industries in parallelizing existing computer codes. The researcher tasked to check it out soon reported back that there was a lot more to Sandia than just a software shop that could parallelize code.

Sandia National Laboratories is the US nuclear weapons complex's engineering laboratory. Sandia employs 8,000 engineers and scientists with an annual budget of $2 billion. Its two principal facilities are in Albuquerque, New Mexico, and Livermore, California. Sandia, too, was learning to adapt to change.

A series of visits and exchanges soon established that Sandia's capabilities in experimental device fabrication, testing, computational simulation, verification, and validation exceeded anything known previously to Goodyear scientists and engineers.

Ever since 1949, when President Truman spun off Sandia from the Los Alamos National Laboratory, Sandia had assumed responsibility for engineering most of the nuclear arsenal's components, except for the fission/fusion packages themselves. During the Cold War, new devices were designed, tested, produced, and deployed in weapons engineered in Sandia's laboratories and test facilities. Sandia's existence wasn't even public knowledge for most of that period. By 1992, however, other priorities had begun to emerge. The Department of Energy (DOE), under the auspices of the National Competitiveness Technology Transfer Act of 1989, had tasked all DOE laboratories to transfer advanced technology to US industry to improve industrial competitiveness. A previously secret lab had been tasked to do unclassified work with industry!

An even bigger change came in 1992, when President Clinton declared a moratorium on nuclear testing. So for a completely different set of reasons than Goodyear's, Sandia, too, was mandated to eliminate "on-the-road" testing.

A series of visits and exchanges soon established that Sandia's capabilities in experimental device fabrication, testing, computational simulation, verification, and validation exceeded anything known previously to Goodyear scientists and engineers. Furthermore, Sandia had been tasked to transfer some of those capabilities to US industry. Who better for technology transfer than the only remaining US-based original equipment manufacturer of tires?

But why did it take a nuclear weapons lab to help a company simulate tire performance?

Tires: The Hidden Complexity

> The pneumatic tire represents one of the most formidable challenges in structural design. Truck and passenger car tires must provide thousands of miles of tread life, remain undamaged during frequent encounters with potholes and foreign objects on the pavement surface, and operate with minimum rolling resistance to enhance fuel economy.… Tires must provide steering and braking forces under all weather conditions for safe vehicle operations.[1]

Although tires appear simple, under the surface they're anything but. A typical passenger car tire can consist of five to 10 reinforcing components, including steel beads that keep the tire mounted on the wheel or rim; a carcass of polyester or nylon that encloses the air cavity; two layers of steel belts of varying width that are cut at bias angles to provide additional stiffness in the contact patch's plane; and an optional layer of nylon or aramid fabric that encircles the steel belts for high-speed rated tires, with a tread on the outside. Such reinforcing components are cables of varying construction and materials, not single fibers.

Surrounding all these reinforcing material layers are differing rubber compounds, each designed to serve specific functions. The inner liner slows air diffusion to maintain the tire's inflation pressure. The sidewall is compounded for abrasion resistance in case the tire hits a curb. The tread is formulated to provide wet traction, dry traction, long tread life, and resist tearing. Near the rim, there are stiffening elements, called apexes, that make the tire more responsive to steering inputs and wedges under the steel belts' outer edges to keep them flatter and in contact with the road's plane. In addition, each rubber compound's properties are adjusted for its particular tasks. For example, the tread compound's hysteresis must balance traction, wear rate, and energy consumption. (Hysteresis is a measure of the amount of energy dissipated each time the rubber is deformed or deflected.)

The reinforcing components and their surrounding layers of rubber compounds are axisymmetric. That is, if you cut through the tire with a plane that includes the axis of rotation, the geometry of those materials doesn't change as the tire rotates; they form a *tire carcass*. The tread pattern, however, does change around the tire's circumference.

Because the tire is a flexible, pneumatic structure, these components deform significantly as the tire rolls down the road. Strain levels in excess of 40 percent occur on smooth roads, with much higher levels experienced when hitting potholes or road debris. In 40,000 miles of use, a passenger tire will experience approximately 30 million stress-strain cycles. The rubbers themselves have tensile moduli orders of magnitude lower than the reinforcing components, such as steel belts. Most critically, however, rubber is nearly incompressible with a Poisson's ratio approaching 0.5.

All these factors and more combined to make creating tire models complex and laborious, with solution times on the order of months for simple models running on a then state-of-the-art Cray Y-MP. In short, the problem was tough enough to be challenging and offer Sandia spillover benefits for modeling nuclear weapons components.

Goodyear and Sandia: The CRADA

Having established, through a series of meetings and workshops, that modeling tire performance would be a challenging task, teams from Goodyear and Sandia began discussing their collaboration's legal framework, which was established by the Federal Technology Transfer Act of 1986. Among other things, the Cooperative Research and Development Agreement (CRADA) required the assignment of intellectual property rights, documentation of Goodyear's eligibility, and the definition of tasks and payment terms.

In all negotiations, both parties adopted a critical philosophy: the final agreement had to be win-win between peers. Both parties were stepping outside their comfort zones of familiar partners and suppliers. Neither knew whether or not the CRADA, with its technical challenges, would prove beneficial to either party, let alone both. Both recognized that technical solutions would have to be developed over a period of years and that they needed to accrue intermediate products of technical value to both parties over shorter time scales. As the sole surviving US-based manufacturer of original equipment tires, Goodyear clearly satisfied Congress's intent to improve US industrial competitiveness.

The parties defined tasks during the modeling workshops. It was clear from the beginning that there were no off-the-shelf solutions to Goodyear's problem, but with its experience modeling a nuclear device's diverse components, Sandia possessed an incredible breadth and depth of relevant experience. The tasks were well defined. The times were, in hindsight, optimistic.

During a CRADA, the industrial partners must compensate the government for the full cost of the national lab's activities. However, the total annual expense of a Sandia employee is several times that of an industrial colleague. That difference in rates could've been a deal-breaker when the CRADA was initiated. Fortunately, to stimulate industrial collaboration, in the 1990s, the DOE funded some or all of the labs' portion of the work with industry and thus reduced industry's financial risk. So long as the industrial partner's share of the total costs exceeded 50 percent, the DOE usually funded the laboratory's costs. Thus, for the initial exploratory work, industrial partners didn't have to write substantial checks to the government. Had that funding not been available in 1993 when the CRADA began, Goodyear's costs would've doubled and the collaboration wouldn't have occurred.

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Audacious Objectives

With DOE funding obtained, Goodyear and Sandia engineers and scientists began working together. The team chose a tough technical and business objective to direct its efforts—simulating treadwear testing. For passenger tires, treadwear testing is the longest prototype test and measures how many miles the tire lasts and whether the tread wears evenly. The tests are run on standard road courses on fleets of vehicles driven at legal speeds for up to 24 hours a day until the tires are fully worn. If a treadwear objective isn't met, Goodyear modifies the tire design—sometimes manufacturing a new tire mold and producing the new tire—and begins testing again. Each iteration of this process averages four to six months; this is a lengthy process, but the results are critical to customer satisfaction.

In 1994, the largest tire model that a Goodyear analyst had successfully solved had 90,000 degrees of freedom (dof). That analyst had spent three months creating the model and getting it to converge. The model didn't incorporate a tread pattern, however, nor did it include the effects of cornering, braking, or acceleration. To incorporate the effects of the tread pattern on treadwear, a back-of-the-envelope calculation established a minimum goal of a 250,000 dof model. Because compute times for commercial solvers scaled roughly as the cube of the model size, and the model had to be exercised through many other test conditions (as previously noted), the team estimated a 15.6-year runtime on a Cray Y-MP with more memory than was ever produced for that machine. Clearly, commercial solvers wouldn't displace prototype building and testing.

At a quarterly progress meeting in Albuquerque, however, two Sandia researchers proposed an alternative approach that might scale linearly, rather than cubically, with model size. With Goodyear's encouragement, a 250,000 dof test problem was constructed and rotated. It ran!

As the teams continued to work on solver strategies, they identified model creation as a rate-limiting step for the simulation process.

Although Sandia's efforts to this point had been funded by DOE matching funds, both parties agreed that some of the efforts would be quite tire specific and should be funded by more direct contributions from Goodyear. Based on that test problem's success, the Goodyear team proposed and sold a million-dollar budget with the objective of simulating treadwear in a fraction of a year—a truly audacious goal. The check was written and deposited in a Sandia account to fund further development.

By 1996, concentrated efforts were underway to make the test solver a robust production solver for various tire designs and test conditions. On a discouraging note for US industry, however, DOE matching funds for technology transfer were being reduced; by 2000, they were eliminated altogether. In retrospect, as successful as the Goodyear/Sandia CRADA proved to be, it's highly unlikely that it would've started without DOE matching funds.

Dual Use

It might seem that a nuclear weapons engineering lab and a tire company have few common goals, but their interests converged on an extraordinarily tough computational mechanics problem that was a challenging test for the lab's new computational algorithms. In 1996, as the potential benefits to Goodyear became clearer, the director of Sandia National Laboratories testified to the US Congress that Sandia was able to solve previously intractable nuclear weapons problems as a result of the collaboration. Because both parties quickly saw tangible benefits, the basis for a long-term partnership was established.

Creating the Model

As the teams continued to work on solver strategies, they identified model creation as a rate-limiting step for the simulation process. Both the carcass and the tread proved to be uniquely difficult. Fortunately, Goodyear's previous investment in its tread and carcass design systems provided both geometries and material identification for the tire's components.

Because rubber is nearly incompressible and viscoelactic, and because many key attributes of tire behavior result from rubber components going into compression at large strains, the computational problem is highly nonlinear. This class of problems requires meshing with hexahedral elements for accurate solutions. Hexahedral elements (hexes) are shaped like six-sided sugar cubes. Meshes with hexes are difficult to create for complex geometries such as tires, and the process is time-consuming and difficult to automate. Nevertheless, they're essential for accurate solutions. Goodyear had recognized the need to automate the meshing process; fortunately, meshing was a subject of key strategic importance to Sandia as well.

In addition to these technical difficulties, the team soon came to the conclusion that, to make SBE design a routine tire design process and to ensure that the design intent was incorporated properly, routine analyses had to be done by tire designers, not finite-element analysts. Because of the industry-specific requirement to adapt the simulation process for tire designers, a Goodyear team was formed to build model creation and post-processing software. At that time (the mid 1990s), one or two commercial software systems were available, but the team nonetheless concluded that it would be easier to create a system from scratch. Sandia's contributions focused on mesh creation, a dual-use technology.

Verification and Validation

Verification of the computational algorithms' accuracy and validation that the model included the appropriate physics were critical to the development and acceptance of SBE design. Engineers' natural skepticism regarding radically different tools ensured lots of attention to the algorithms and their physical meaning. That skepticism was also the most difficult psychological barrier the team encountered. As one senior development executive put it, "I know modeling and simulation are coming. I just hope I've retired before we have to implement them." The team ultimately was successful, but both of that gentleman's statements proved true.

On the solver development side, the Goodyear-Sandia team bore down on ensuring convergence; eliminating the bugs that killed runs for no obvious reason; and cross-checking results whenever possible with other computations using different, but perhaps much slower, algorithms. All the usual concerns regarding the difficulty of debugging software applied. After much effort, the team realized that the solvers were becoming robust as the number of runs climbed into the tens of thousands.

In parallel with software development, the performance prediction teams were tasked with developing engineering criteria that correlated with existing, subjective design criteria such as "steering precision" and "on-center feel." The vehicle manufacturers' experienced test drivers assign tire ratings based on many such subjective criteria; however, subjective feelings don't "pop out" of a finite element analysis. The vehicle test engineers and research scientists therefore collaborated on engineering criteria that they could quantify and relate to these subjective ratings from an engineering mechanics perspective. The resulting engineering metrics became the basis for the detailed tests used to validate the simulation results. As the application of SBE design to tire performance requirements increased, validation emerged as a continuing process for the engineering function.

Compute Power

From 2000 on, the SBE design system's verified and validated capabilities grew, requiring an increasing number of compute cycles—a good problem to have. Goodyear's IT team decided that Linux clusters were appropriate machines for the new parallel codes. Sufficient machine capacity, however, became an issue that had to be addressed more frequently than every three years, which was when existing leases expired. Furthermore, Goodyear had two primary technical centers—in Akron, Ohio, and Colmar-Berg, Luxembourg—and both required sufficient compute power to service their engineers' design efforts.

Achieving accurate machine capacity planning was difficult. Demand for compute resources increased exponentially, but the exponent's exact value was always in doubt. Planning too small slowed simulation's diffusion throughout the organization; planning too large wasted money. The solution quickly became clear: lease new equipment annually and closely integrate machine-capacity planning with the computational mechanics group's tool deployment plans.

However, annual machine leases threatened to seriously complicate administration of the high-performance computing (HPC) facilities. One solution would have been to standardize on a single vendor's product line, but the resulting standardization would have come at a significantly higher price because it would eliminate competition. Another solution would have been to increase the support staff to handle more machines—another expensive option.

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After much discussion and debate, a new process was developed. Approximately every year, both technical centers installed a new cluster that was part of a global purchase from a single vendor. The machines were installed, however, with a three-month offset in time from one another. For the first installation of a new machine, the system administrators from the technical center not receiving the machine would fly to the other location and work side-by-side with their colleagues to get the new cluster up and running quickly. When the second machine was installed, the process was reversed. The new clusters typically were released for validation testing within a week. With this process and these successes, the system administrators became a global team that took advantage of the six-hour time offset between technical centers to support each other and monitor all the clusters day and night. In 2006, *CIO Magazine* recognized these efforts at their annual awards ceremony as one of the five most innovative uses of IT.

Another Financial Crisis

Before getting to that ceremony, however, another financial crisis gripped Goodyear in 2002.[2] The company was still highly leveraged and profits had turned to losses. The chairman who had sponsored SBE design's development soon retired. The new chairman, as part of his recovery plan, wanted new, exciting products that would lift both sales and revenues and energize the dealer network. The standard process of developing tires by building and testing prototypes took roughly three years; this new exciting passenger tire, however, had to be developed in time for the North American dealer conference, which was less than one year away.

Although SBE design had made great progress, no one had yet made the leap of faith to design a radically new tire from scratch using simulation—nor did anyone know how long that process would take. The lead engineer for the new product later reflected on his situation: "I didn't know if modeling could meet the challenge, but I did know that the iterative process of building and testing tires couldn't." A team from Sandia, computational mechanics, and IT immediately began assisting the tire design team as it committed to developing the critical new product through simulation rather than prototype building and testing.

Other countries, recognizing the strategic importance of SBES, are allocating significant resources to develop capabilities in close collaboration with their industries.

The results made Goodyear history. The company introduced a radical new tire—the Assurance, featuring TripleTred Technology—on time at the dealer conference. The tire delivered a performance combination on dry, wet, snowy, and icy roads that exceeded competing designs and still offered excellent treadwear and noise performance. In addition to numerous industry awards, the design team and Sandia won an R&D 100 Award in 2005, both for the new product and the process by which they created it.

The Fruits of Success

With the success of Assurance, demand for SBE design soared. Tire by tire and tire-line by tire-line, Goodyear updated its development process. The result was an unprecedented string of new product awards and increased sales. Realigning resources from prototype building and testing to simulation-based design resulted in a reduction in prototype expenditures of $100 million annually.[3] Goodyear had exceeded its original objective. By investing those savings in other R&D areas, the company not only substantially improved its competitive position, but most important, reduced its new product development cycle for passenger tires from three years to less than one. The team could now solve a simulation estimated to require 32.2 years of computation time using conventional methods in less than five working days![3] Simulation-based engineering design let teams develop new products nearly as quickly as the competition could reverse-engineer and copy them, thus providing substantial competitive advantage. Time *was* of the essence.

US Industrial Competitiveness

By 2005, SBE design for new product leadership became one of Goodyear's standard business strategies.[4] Unfortunately, however, US industry as a whole today is in danger of falling behind other countries in its adoption. A series of blue-ribbon panels has concluded that America's economic prosperity will depend on greater emphasis on science and technology in general[5] and on SBE and science (SBES) in particular.[6] Furthermore, other countries, recognizing the strategic importance of SBES, are allocating significant resources to develop capabilities in close collaboration with their industries.[7]

For example, the Partnership for Advanced Computing in Europe (PRACE) is a government-university-industry collaboration to advance SBES. PRACE will provide European universities and companies algorithms, solvers, and infrastructure for "world-class leadership supercomputers with capabilities equal to or better than those available in the USA and Japan" (www.prace-project.eu). PRACE's First Industry Seminar showed the need and benefits of a government-academia-industry collaboration giving Europe "the HPC-level of resources for industrial advances and R&D competitiveness in various domains."[8] PRACE's second seminar concluded that HPC is strategic for the competitiveness of science and industry and that one of the key goals should be to understand industrial needs and expectations.[9] In short, Europe is developing a plan and allocating resources to assist its universities and industries in the conversion to SBES.

While the Europeans forge ahead and all the US study panels agree on the need for more emphasis and spending on SBES, the Goodyear case study reveals areas of concern regarding SBE design adoption across US industry.

- As a $20 billion annual revenue corporation, Goodyear had the technical and financial resources for advanced technology development and collaboration with a national laboratory that are unavailable to many corporations.
- Goodyear had the foresight to begin developing its simulation capabilities nearly a decade before they were critically required.
- Back in 1993, the US DOE's technology-transfer funds reduced the cost and thereby the perceived risk for a then-novel partnership between a tire company and a nuclear weapons laboratory.

DOE's technology-transfer funding for industry is no longer available. Given current financial constraints on industry, which companies will choose to initiate advanced technology development in support of SBES? Of those companies, which will make the actual switch from prototype- to simulation-based new product development and manufacturing? Given the immediacy of the need to reinvent portions of the US industrial base and the perceptions of high risk, shouldn't the question become, "How will the US stimulate and accelerate the switch to SBE design and manufacturing?"

For some products and industries, existing commercial analysis software neither sufficiently incorporates the "physics, chemistry, or biology of the problem" nor scales to petaflops computing. Therefore, the solution surely involves creating business plans for government labs that task and fund collaboration with US industry, together with incentives and structures that reduce the risks for both. Given the knowledge and expertise of universities, HPC centers, and hardware and software vendors, a stable, sustainable SBES "ecosystem" must include their contributions as well.

Hopefully, today's economic crisis will provide the stimulus for all parties to discuss, explore, experiment with, and adopt scenarios that result in the Goodyear case study being a leading-edge example of the conversion to SBE rather than an unusual one.

Acknowledgment

Assurance, featuring TripleTred Technology, is a trademark of The Goodyear Tire & Rubber Company, 1144 East Market Street, Akron, OH 44316.

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