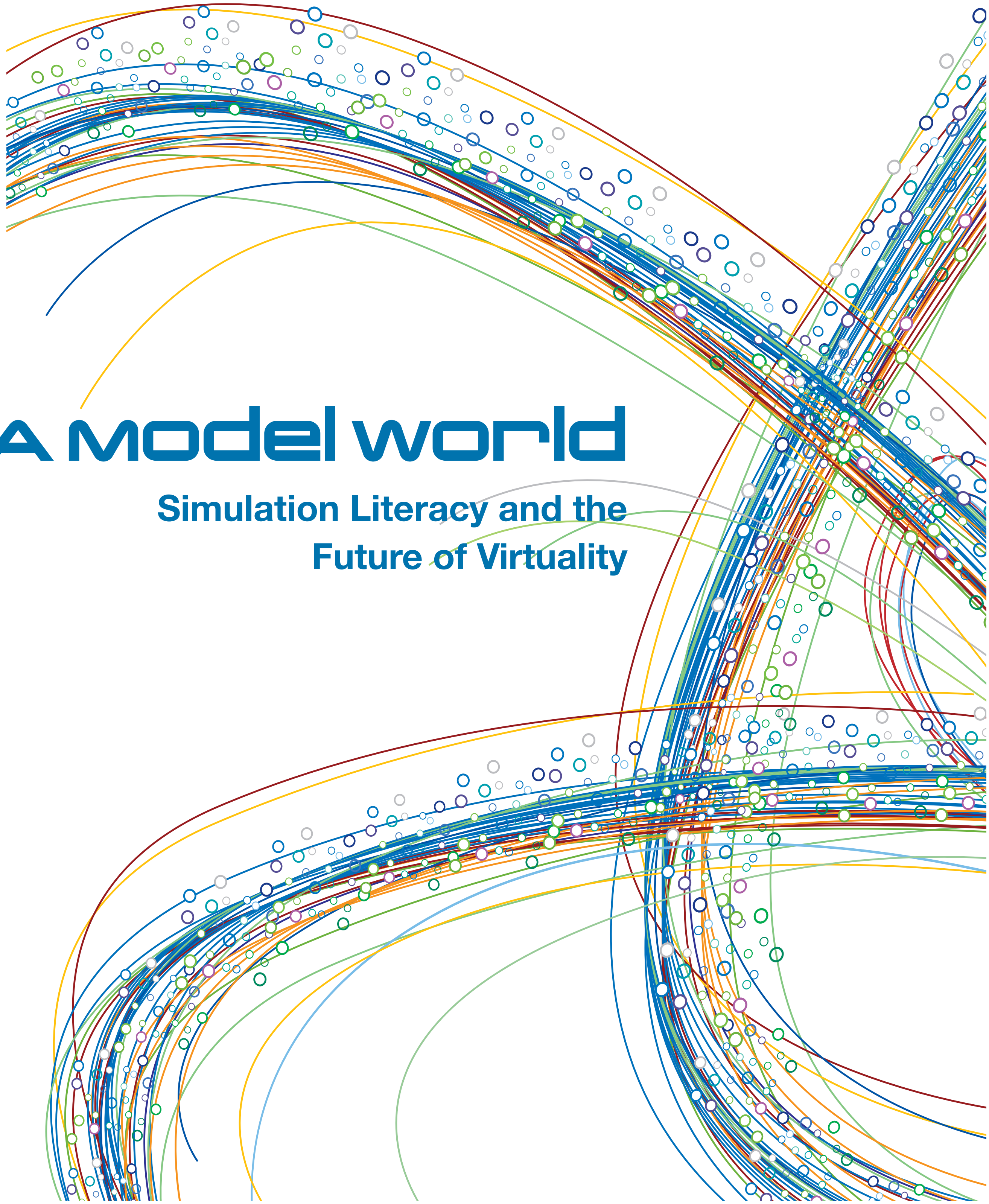
A model world

Simulation Literacy and the Future of Virtuality



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INSTITUTE FOR THE FUTURE

About the ...

INSTITUTE FOR THE FUTURE

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contents

introduction

A new language is emerging that will transform how we conduct business, make life decisions, and interact with our world over the next decade: it is the language of simulation. At the most basic level, a simulation is an imitation of a real thing, experience, or process. But in recent years, it's become possible to create computer simulations that are much higher fidelity and more accurate than ever before. In the next decade, the best simulations won't be judged by how realistic they are but how real they are. They will become real in the way that the Internet has become real over the last decade—not only as a platform for learning or academic science, but also as a platform for providing human social interaction and commerce; as a platform for designing the world in real time; and as a platform for inventing and reinventing our individual lives. With some simulations, we will twist the knobs, press "go," and see what happens. In others, we will be key players, interacting in digital space with virtual artifacts, phenomena, and each other. Some simulations will even play out at the intersection of the virtual and real worlds, enabling us to bring a sense of physicality to our digital data.

We will program the physical world and use it as a training tool. We will run entire businesses in simulation before risking a dime in the marketplace. On-the-job training, from medical procedures to the operation of heavy machinery, will start in the virtual realm where mistakes are free of consequences. Even the choices we're faced with in our lives—attend graduate school or stay in the working world, seek a promotion or find a new job, go vegetarian or try out a new diet—will be converted into code that we can "run" before making up our minds. We'll even simulate phenomena that we don't entirely understand, finding value in the process and the end state without getting distracted by the details that lie beyond our scientific knowledge.

Indeed, computing pioneer Alan Kay believes that we are at the dawn of a new literacy, a "simulation" literacy, where competence in creating, understanding, and interacting with simulations will give us a leg up at work and home. In the coming decades, computer simulation will become a required language for all of us.

1 Getting Real

A SHORT HISTORY OF SIMULATION

The history of simulation provides a guide for understanding, in broad strokes, its future evolution. During much of the 20th century, simulations were used to train workers to perform complex tasks, or to model the behavior of complex systems. These simulations didn't just adopt the latest technology: they led to fundamental breakthroughs in computing. Today, in a new generation of simulations, these two traditions of training and modeling are starting to merge, and developers are creating simulators that place users in increasingly complex, ambiguous situations. This suggests that in the future, training will continue to be an important but increasingly routine use of simulation. The cutting edge of simulation will move to two other areas: exposing skilled workers and professionals to emergencies, disaster response, and crises; and developing tools to explore different scenarios or development paths for organizations and individuals.

Simulation and Training

Military training systems date back to ancient times, but virtually all crafts and professions were organized around apprenticeships that trained people on the job, or academic programs that focused on theory. Simulation, as a form of training that allows practitioners to learn new skills without the risks of failure, became widespread only in the 20th century, thanks to the growing professionalization and technical demands of occupations. In the last century, medical schools, military academies, and business schools all faced the common challenge of simultaneously teaching theoretical knowledge and preparing students for the real world.

Thus anatomical dissection and clinical programs in medicine, mock trials in law, and field exercises in military and police academies became central to the curricula of professional schools. These simple simulations were joined during and after World War II by electro-mechanical simulators: flight simulators that familiarized pilots with the controls and behavior of new aircraft, and driving simulators that emergency personnel used to learn how to navigate extremely large and powerful vehicles. These established the value of simulation in professions in which technological or knowledge bases changed rapidly.

One of the earliest flight simulators, the Link trainer, was developed by Edwin Link in the late 1920s. During World War II, some 10,000 Link trainers were used to train new pilots for the allied nations.

Source: wikipedia

During the Cold War, military and emergency training became even more simulator intensive, as soldiers and police constantly trained to keep up with the latest innovations in weapons or vehicles. Until the 1980s, these simulators were very expensive to build, and demand for training time far exceeded supply. But as technology evolved and computers moved to our desktops, the growing power of graphics workstations and personal computers had two major effects on training simulators. First, it gave them greater flexibility: the same flight simulator could be programmed to simulate several different jets, or driving simulators to simulate fire engines one week and patrol cars another. Second, it brought more realistic simulators within the reach of more professions. Twenty years ago, military officers trained with expensive tank simulators; today, equipment and vehicle manufacturers use commonplace simulators to train operators of earthmovers, bulldozers, and dump trucks.

Simulation in Science and Engineering

Training simulators were designed to refine skills, and to teach highly complex tasks, such as landing an airplane or dislodging a rooftop sniper. At the same time, another kind of simulation, aimed at modeling the behavior of sophisticated built or natural systems, emerged in the sciences and engineering. These simulations brought together three formerly separate kinds of models. The first is the mathematical model in the hard sciences, which seeks to explain the rules guiding natural processes and phenomena. The second is the engineering model, for example miniature tidal basins, aircraft models, and crash test dummies, which were used to test and refine new technologies. The third is the natural model in the biological and medical sciences: animal organs such as the giant squid axon and pig heart, which were similar enough to human organs to be useful in basic research.

Computer modeling, which began in the 1950s and advanced rapidly, united these traditions. For example, models of weather systems, colliding galaxies, and chemical structures have a mathematical foundation, but can be prodded, tweaked, and experimented on. For decades, mainframe computers made high-end simulation expensive and scarce, and in some fields (climate science, for example), size still matters: the most realistic, detailed simulators still require bleeding-edge hardware and software. But since the 1980s, with the arrival of inexpensive powerful desktop computers, cheap supercomputer clusters, and programming platforms such as Java, Microsoft's .NET, and MATHLAB, simulation has become more realistic and cheaper to create and improve. Indeed, the explosion of research in nonlinear phenomena, emergence, and network sciences has been facilitated by the growth and proliferation of cheap computing resources.

Programs such as Java, Microsoft's .NET, and MATHLAB have brought supercomputing into the home, providing cheaper, easier-to-use, and more realistic simulation options to the everyday user.

Source: www java.com

Simulation Today

Today, what used to be an expensive, rare tool is common in business, in training programs, and in entertainment. Hedge funds develop fantastically complex programs to detect and exploit small market changes, while small investors use simple, Web-based simulations to follow stocks. Military simulators teach grand strategy and small-unit tactics, sometimes using graphics and physics engines borrowed from video games.

Indeed, video games have not just contributed technical advances to simulation. Games such as *Civilization* and *Age of Empires* give players the ability to design armies and conduct military campaigns. Will Wright's *Sim* series, one of history's most popular video game franchises, teaches players how to design societies and cities. Wright's forthcoming *Spore*, described as an "evolution simulator," lets players create species that evolve from primordial swimmers to galactic travelers. Just as *Entropia* and *Second Life* are fun-ride versions of CAD/CAM systems that unintentionally teach players industrial design, complex games such as *Sim City* have acquainted a generation of players with the idea of simulation as an exercise in world building.

The cutting edge of simulation is starting to merge training and scientific simulation to combine realistic models of technologies—weapons, vehicles, etc.—with highly sophisticated virtual environments and emergent behavioral models. The results are simulations that don't just train users in specific tasks, but give them experience working in complicated, volatile environments. For example, developers of SWAT team simulators are starting to incorporate psychological profiles that let virtual perpetrators behave more realistically. The environments are made more realistic through the addition of photographs or blueprints of real spaces. The hope is to eventually create simulators that first responders can use to realistically "experiment" with different scenarios. In this scenario, police at a hostage site might load up the floor plans for the building and psychological profiles of the assailant and hostages, in order to assess the viability of several plans before acting.

The use of embedded computers has led to another important innovation: the creation of "simulator modes" for real vehicles, weapons platforms, and other technologies. For example, navigators and weapons officers stationed on the latest generation of U.S. submarines and aircraft carriers can run simulations at their stations, or participate in exercises that link together several vessels. When combat takes place on a computer screen, it's relatively easy to have the screen display a simulation rather than a real situation.

Both cases share an important common point: they're starting to merge simulation with real work and the real world. They're transforming simulation from a tool to train users in particular skills, to a tool that helps users anticipate the possible outcomes of specific engagements and decisions.

Will Wright's upcoming game *Spore* is perhaps one of the most ambitious simulation games. Building off Wright's *Sim City* franchise, *Spore* simulates evolution itself.

Source: www.spore.com

2 FORCES SHAPING THE EVOLUTION OF SIMULATION

While the history of simulation is long, new technologies, combined with incremental advances in familiar technologies, are now enabling players in a much wider range of business domains to leverage the power of computer simulation tools and processes. The following are the major trends that are intersecting to give rise to this new era of digital simulation.

Availability of Abundant Computing Resources

Over the next five to ten years we will overcome limits in availability of our computational resources. While today's high-performance computing applications are mostly limited to capital-intensive industries such as petroleum exploration, aircraft and automotive design, and pharmaceuticals, over time these capabilities will migrate to mass markets and eventually into the hands of consumers. Ray Kurzweil postulates that by 2019 a $1,000 computing device (in 1999 dollars) will have the raw computational power of a human brain (though whether this will be enough to produce artificial intelligence that rivals humans is a matter of debate). So while advanced simulations such as climate modeling have historically run only on the fastest supercomputers in the world, we will soon have those supercomputers on our desktops.

"There are roughly a billion PCs on the Internet, and they're 98% available for computing," says Larry Smarr, professor of computer science and engineering at the University of California, San Diego (UCSD) and Director of the California Institute for Telecommunications and Information Technology (Calit2). "That's like having a billion-processor computer just sitting there, with nobody using it."

These machines will compute and generate interactive, photorealistic simulations in real time allowing a user to explore, recombine, and analyze in a nearly endless variety of ways. Meanwhile, high-speed wireless networks and ubiquitous broadband will enable us to share and interact with these simulations from anywhere in the world. William Gibson's definition of cyberspace as a "shared hallucination" will finally ring true.

Exponential Growth in the Amount of Visible Data

A simulation is only as good as the raw data you feed it. For example, a computer model of a new car engine design will have no basis in reality if the data fed into it isn't reflective of the real world. As they say, garbage in, garbage out. But just as simulation technology is rapidly improving, so are systems for data collection. Pervasive sensor networks open up new vistas for scientists and engineers to observe physical phenomena and react to them. Every object, every interaction, and every observation becomes a piece of data to analyze and feed into simulations.

Kevin Kelly, a founding editor of *Wired* magazine and author of several books on digital culture and technology, talks about the dawn of a new science called “zillionics,” where unrelenting rivers of sensory data will flow day and night from zillions of sources. Whether they’re tiny “motes” that form ad hoc networks to monitor environmental phenomena, or implantable biochips that keep constant vigil on our vitals, these sensors will collect the raw data that can be used to build new simulations and also verify and validate existing models.

Emergence of a Mathematical View of the World

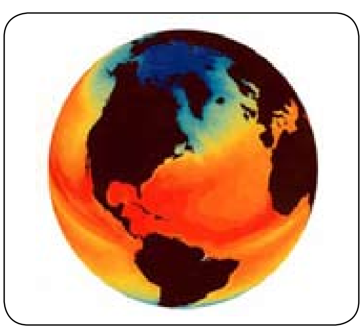
The engine underlying every computer simulation is a mathematical model. As famously defined by control theory pioneer Pieter Eykhoff, a mathematical model is “a representation of the essential aspects of an existing system (or a system to be constructed) which presents knowledge of that system in usable form.” A mathematical model is used to describe a system with equations that calculate the relationships between variables. Our models are getting better: there is a growing informal library of mathematical models used to describe systems ranging from biological processes and computer networks to factories and highways.

“A model of [each of these systems] has proved to be more cost effective, less dangerous, faster, or otherwise more practical than experimenting with the real system,” says Roger Smith, Chief Scientist for the U.S. Army Program Executive Office for Simulation, Training, and Instrumentation.

In the next decade, one could imagine that these discrete chunks of esoteric mathematics might be snapped together like Legos to create complex simulations that model a variety of phenomena all at once. For example, a physics engine that models a car engine may be mashed up with an interactive avatar that drives a virtual auto through simulated rush hour conditions to see how the start/stop affects gas mileage. For the simulation designer and user, the mathematics under the hood remains essential but becomes invisible.

Keith Devlin, Executive Director at the Center for the Study of Language and Information at Stanford University, coined the term “soft mathematics”—the application of mathematics to individual human beings by incorporating psychology, sociology, linguistics, economics, and political science. In the coming decades, these areas will become increasingly “mathematical.” As our mathematics emerges, we too will be grist for the simulation mill.

Climate models like this one use quantitative methods to simulate the interactions between oceans, land surface, and ice. They are used for a variety of purposes, from study of the weather, to projections for the future climate.



Source: www.lbl.gov

3 the future

SIMULATION BECOMES A NEW LITERACY

The future of computer simulation will be a shift in both form and function. As the spectrum of applications broadens, so too will the ways we interact with simulations and, eventually, drag these digital models into the physical realm. In the sciences, we're backing into a situation where we sometimes create simulations that work, but whose inner workings are as modestly elusive—or as dizzyingly incomprehensible—as Nature herself. Simulation will evolve from an exclusive, occasionally used practice to something used every day: we'll use simulations to explore the consequences of even simple decisions. Simulations will also become increasingly physical, as bits move from pixels on screens and into atoms in the world. Finally, tools used to model statistical probabilities and changes in businesses and economies will become tools for living.

Simulation Does Science

From searching for causality to simulating states

Centuries ago, Italian astronomer and physicist Galileo Galilei declared, "The book of nature is written in the language of mathematics." History proved him right: falling bodies, fluid dynamics, galactic rotation, genetic mutation—these and countless other phenomena have been described using elegant mathematical formulae. For centuries, mathematics has provided the sciences with reliable means to understand and predict natural events.

That is, until now. Simulations have been used to model and predict the behavior of increasingly complex systems, or to design new systems. But one unexpected consequence has been that these simulations have sometimes taken on lives and logics of their own: the tools work, but they don't necessarily help us understand the phenomena that they were designed to describe.

Take, for example, evolutionary design techniques, in which computers "evolve" and test solutions to technical problems. These techniques can now produce successful designs for everything from sorting programs to new drugs to spaceship antennae. With these tools, evolution can happen a billion times faster in a computer than in nature: five million years of evolution can happen onscreen in a day. The Cornell Computation Synthesis Lab has a simulated environment in which mobile robots evolve. Rather than taking human-like forms, the simulation has produced nine-legged centipedes, marching pyramids, and even stranger creatures. NASA's Evolvable Systems Group uses simulated evolution to create antennas for use on space probes. Architects have begun to adopt some simulated evolution principles in the design of buildings and industrial infrastructure. Bioscientists have begun to use it as a methodology for creating novel drug molecules. Even game designers are starting to use evolutionary design processes to generate unique aspects of game worlds and characters. As often as not, however, these evolutionary simulations generate results that test the limits of our scientific understanding: they work, but not according to rules we've yet discovered. When he created a program that artificially evolved trees, even Oxford biologist Richard Dawkins admitted, “Nothing in my biologist’s background, nothing in my 20 years of programming computers . . . prepared me for what actually emerged.”

Agent-based modeling is another form of simulation that has created interesting, but sometimes inexplicable, results. One of the more fascinating aspects of agent-based modeling is that it often generates emergent phenomena—highly complex dynamics and behaviors that are not possessed by members of a group, but by the group as a whole. Emergent dynamics seem to be at work in everything from flocking behavior, to predator-prey dynamics, to ecological collapses, to riots and genocide. For example, an interdisciplinary team at the Center for Social Complexity created an agent-based model of communities in the Southwestern U.S. desert. They found that the communities’ growth and collapse under ecological pressures closely matched the fall of the Anasazi. But scientists and philosophers are nagged by a basic question: Do these simulations reveal the underlying rules governing real physical and social phenomena, or just produce something that looks similar? Emergence can do a good job of modeling natural phenomena and displaying results that look fairly accurate, but we have yet to devise experimental tests that verify that emergence works the same way in the real world as it does onscreen.

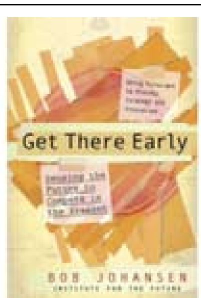
This creates a curious situation for science. Evolutionary design, emergence, and other forms of simulation have been used by pure scientists in a variety of disciplines, and proved their utility in everything from electronics to biology to animation. However, their pragmatic utility masks a deeper problem. Science has always been as much about understanding nature as affecting it, and the former has been a prerequisite for the latter. This close relationship is beginning to fray, and it portends a growing disconnect between our ability to create new technologies, to change our world, and to understand our technologies and anticipate change.

Simulation Builds Calluses

From scenario planning to living scenarios

IFTF Distinguished Fellow Bob Johansen writes in his book, *Get There Early: Sensing the Future to Compete in the Present*, that simulations help us learn to be comfortable being uncomfortable.

Doug Campbell of the U.S. Army War College says that, “Simulation builds calluses.” As the tools to create advanced simulations move from supercomputing facilities to our desktops, simulations will become trusted advisors in our daily lives. In the next decade, it may be considered naive not to run a simulation before releasing a new product, starting a business, or even making a major decision in life. The future is uncertain, and therefore uncomfortable. As Institute for the Future (IFTF) Distinguished Fellow Bob Johansen writes in his book *Get There Early: Sensing the Future to Compete in the Present*, “Simulations help us learn to be comfortable being uncomfortable, they allow you to get there early without committing to go there at all.” They show us what could happen without it happening. In the business world, simulations enable us to create an alternate reality, one that becomes actionable as a business strategy as well as a continuously useful tool for operational management and decision making.



Source: IFTF

DayJet embodies that mindset. The new airline plans to revolutionize business travel by utilizing agent-based modeling, a method for understanding and simulating emergent phenomena, to simulate regional business travel. After answering a few questions—Where do you want to go? When do you need to be there? How early can you leave? How many seats do you need?—DayJet software will, within five seconds, map a best-case route and generate a detailed price quote. DayJet's goal is that 85% of its offers to potential customers will not be refused. On the surface, this may seem like a basic routing problem, but the DayJet solution reflects a far more complex system than anything the aviation industry has tried to date.

According to Jim Herriot, a pioneer in the modeling of complex systems, DayJet is the first business that "has modeled the entire company—from filing flight plans to disruptions in weather patterns to ticket purchases—before starting operations."

While that kind of business modeling is meant to help organizations make things go right, other computer simulations are designed to reveal worst-case scenarios. Disaster-response teams already depend on the likes of earthquake simulations and pandemic models to help prepare for emergency situations. And the military is at the cutting-edge of simulations, in the form of war games at strategic and tactical levels. Now, simulations are in development to forecast what happens when our virtual infrastructure suffers very real damage. As Web 2.0 technology penetrates enterprise, the threat of cybercrime, viruses, and network attacks will become an even larger concern than it already is today. That's why researchers are building highly accurate models of large-scale networks to stage attacks and test responses in safe environments that replicate real world conditions. While many of these projects were launched as a response to perceived threats to the U.S. cyber infrastructure, the fruits of the research will quickly trickle down to the enterprise level and private network security firms.

By simulating their massive network infrastructures, enterprises will be able to run their own simulated attacks and virus infections to hone their security systems and develop appropriate responses to minimize risk and downtime. We'll be able to answer "what if" questions by playing them out in a simulation.

Simulation Comes off the Screen

From virtual reality to blended realities

Almost two decades after "virtual reality" became a buzzword, the technology is finally beginning to live up to its promises. For a glimpse of the future of virtual reality, one only need visit Calit2 at UCSD. In the 4K Digital Cinema, a projector shows the results of an ocean simulation with graphics that are four times higher than the resolution of HDTV. Next door, a researcher interacts with protein models surrounding him inside a next-generation virtual reality CAVE, like the one developed by the University of Illinois, Chicago's Electronic Visualization Laboratory, this one with 34 projectors to deliver imagery close to the effective acuity of the human eye. Across the room, a Cylindrical Varrier Autostereo VR Display enables the user to fly around a Mars simulation in full 3-D without wearing any glasses. And while virtual reality becomes more immersive, other technologies are bringing the rest of our senses into play. Three-dimensional audio spatialization puts surround sound to shame while haptic devices

The California Institute for Telecommunications and Information Technology (Calit2) houses a 4k digital cinema that offers four times the resolution of the most widely used HD format.

Source: www.calit2.net

translate digital information about a virtual model into force feedback, providing the sensation of actually touching a real object. These sensory technologies, when combined with virtual environments, immerse the user ever deeper into the simulated experience. It's here, at the intersection of the virtual and real, where we find the action.

The Fraunhofer Institute for Computer Graphics Research IGD in Darmstadt is taking a mixed-reality approach for toolmaker Dolmar. The researchers created a chainsaw training system that combines a bladeless chainsaw instrumented with sensors, a plastic tree trunk, and a graphical simulation where the real and the virtual meet. Cameras attached to the plastic tree trunk keep tabs on the chainsaw and translate that data to the virtual image that depicts the tool cutting through a wooden trunk. A vibrating motor installed in the tool gives the user the feel of holding a working saw. The cybersaw isn't "realistic"; it's real, yet it builds calluses without shearing off fingers.

Stanford University anesthesia professor David Gaba applies the power of mixed reality to medical training. The Associate Dean for Immersive and Simulation-based Learning at the Stanford School of Medicine, Gaba is a pioneer in the use of physical patient simulators—sensor- and microprocessor-laden mannequins that can be programmed to exhibit a variety of symptoms and emergency scenarios, from a climbing heart rate to a dangerous drop in blood pressure. The Sim Man device even bleeds simulated blood.

"Most medical schools are very good at teaching normal medical procedures," Gaba says. "The point of simulation training is to expose people to events and challenging situations they have not seen before, but could see, and then use them as generic springboards to teach all the behavioral issues of crisis management, dynamic decision making, leadership and teamwork, and the processing of information."

For the physicians in training, it's not a game. Indeed, it's so immersive that Stanford does not allow simulators to "die" unless the death is planned. The rule was created, Gaba says, to limit the "emotional baggage" of death, even when it's virtual. In these leading edge applications we can see how simulations combined with the new generation of programmable materials will move off the screen and become integrated into physical reality around us.

The Stanford University School of Medicine uses physical patient simulators that exhibit a variety of symptoms and emergency scenarios to train future physicians.

Source: www.laerdal.com

Simulation Builds the Future You

From organizational modeling to personal simulation

What happens when you turn the tools of simulation on yourself? As passive data-mining methods improve, information about our preferences, desires, and history will enable algorithms to advise us on our daily lives. Google's iGoogle personal search page service is just a step toward a system that could someday "know" you well enough to act as a mentor and career coach. According to Google CEO Eric Schmidt, "The goal is to enable Google users to be able to ask questions such as 'What shall I do tomorrow?' and 'What job shall I take?'"

Further in the future is the ability to simulate how your life choices might impact you on the cellular level. What specific side effects are you likely to experience if you take a certain drug? How will a new diet affect your metabolism? Systems biologists are leveraging data from the Human Genome Project to create just these kinds of simulations of our own physiology. At a recent IFTF Technology Horizons Exchange, UCSD bioengineer Berhard Palsson discussed the "virtual human metabolic network" that he and colleagues have created. The researchers tested almost 300 simulations on such biological processes as the synthesis of testosterone and estrogen and the metabolism of dietary fat. In each instance, the simulation's results matched that of real-world data. Palsson's hope is that the model, available for free online, might someday be used to test new pharmaceuticals and make it easy to individually customize your diet for weight control.

Many companies will likely compete to gain a reputation as selling the software that offers the "best" advice. Our own decision-making processes may suffer as we increasingly look to machines to tell us what to do. Simulations become parental figures, digital mentors that we can blame when things don't go our way. The problem is that it's tough to verify the simulations against real life without great risk, and because it's nearly impossible to see how "the other option" might have played out.

4 Mapping the simulacra

NAVIGATING THE MAP

This map is a simulation of simulation. One axis is organized around several important kinds of simulation: situations, disasters, business processes, natural phenomena, and scenarios or futures. The second axis is oriented around major uses of simulation: learning, forecasting, and communicating.

The objects on the map are color-coded to place them in one of four categories:

- Mechanical
- Digital
- Mixed reality
- Future

Simulations that are under development or discussion have dotted lines around them: they are examples of potential future simulations.

The map reveals a couple of big trends in the simulation landscape. First is a gentle shift along the axes. While simulation will continue to be used for training in specific situations, or planning for disasters, one future trend is toward simulating scenarios and futures, and using those simulations for communicating and understanding.

Second, the three categories are roughly historical. Mechanical simulations dominated the first half of the 20th century, and while they are still critical in some niche areas (automobile crash testing, for example), their importance is waning. Digital simulations have risen to prominence in recent decades, are of central importance in the present, and will continue to be important in the future. Mixed reality simulations are relatively recent inventions; however, they are going to be extremely important in the future.

	Building Calluses	Virtual Gets Real	Science of Simulation	Simulating You
TRAINING	Law enforcement/ military: • war games • driving simulator • flight sims	Mixed-reality equipment training Virtual humans (for med school)		Virtual babies (for teens)
DISASTERS	SWAT simulator epidemiology	Crash test dummies Digital city for disaster management	Climate modeling Earthquake simulation	Driving school simulation
MANUFACTURING	Business: • operations research • factory models • stock markets • supply chain (historical example: hydraulic economic models)	Architecture Virtual product design (CAD to product simulation); Circuit design tools Energy use (historical examples: - naval engineering - wind tunnels)	Traffic planning Nanoengineering	
NATURAL PROCESSES		Simulating materials/ systems aging	Social dynamics Cell modeling Ocean circulation Agricultural simulation Virtual surgery Virtual psychology	Diet forecasting Virtual human metabolic network Age simulators
ENTERTAINMENT		Virtual worlds: • *Second Life* • *Spore* • Alan Kay's *Croquet* • Sim games (*Sim City*, *Sim Civ*, etc.)		Dating/matchmaking Theme park rides
FUTURES	DayJet	Science fiction films	City simulators	Google career sim

5 implications

As simulation evolves and becomes integrated into our physical world, we can expect to see a variety of implications. We'll see simulation embedded in the workplace as part of regular daily activities. Design collaboration will move from carefully managed project teams to highly transdisciplinary ad hoc collectives. Finally, workforces will require new skills in simulation literacy but businesses will have to be careful not to favor crisis management skills over basic skills required to keep an organization running daily.

Learning and Training: Simulation Weaves Into the Workplace

As we've discussed, it's clear that simulation will become a more important tool to train basic skills and test workers in crisis conditions. But in some occupations and work environments, simulation may become so common that the lines between simulation and regular work and those between training and doing will begin to blur.

The falling cost of simulation has already begun to reduce the basic cost of training. As this cost continues to fall, simulation will evolve from an episodically used tool to a persistent one. Today, Unmanned Aerial Vehicle (UAV) pilots train on the same systems that they use to pilot vehicles over Iraq and Afghanistan. For workers who perform the same types of tasks throughout the day, and who work mainly with computers or phones, creating realistic simulations would be relatively simple. Imagine, for example, an artificial customer designed to test call-center workers. During off-peak times, artificial customers could present workers with difficult problems, such as a technical question that can only be answered with a call to the factory, or an account problem that tests a representative's knowledge of the outer edges of the Customer Relationship Management (CRM) system; others might be programmed to train workers in dealing with the especially bellicose or forgetful (a growing problem with aging customer bases). Radiologists in Asia or Eastern Europe reading X-rays from U.S. hospitals could be tested with X-rays that show rare diseases or ambiguous or hard-to-spot signs of illness.

These training simulations could also take on a valuable collaborative quality. As Julian Orr documented in his ethnography of copier technicians, workers use stories about difficult problems or customers to share knowledge with their colleagues. Even relatively simple technologies such as copiers develop their own "personalities," influenced by where they're installed and how they're used, and good technicians learn the quirks of individual machines and how to differentiate routine from complex problems. These stories are an essential medium for helping new workers understand the difference, and they're hard to put into databases or manuals, since technicians often use props when telling their stories. Simulations, however, may be a better medium for widely sharing the knowledge that such stories contain. A copier laden with sensors could do more than provide retrospective lessons for new workers. Its problems could be uploaded into a simulated machine, and field technicians could get help from colleagues when dealing with especially difficult machines.

Altering the Design Cycle: Smart Mobs Replace Project Teams

If training simulation could provide one platform for collaborative behavior by sharing accounts of challenging problems, design simulations could provide another, even more powerful platform for collaboration. Today, the pressure to shorten design cycles and create more user-friendly products is driving sports and medical companies to bring users into the design process, and to use tools such as CAD and rapid prototyping to get fast feedback from beta testers. Simulation could further reduce design cycles—and even collapse the distinctions between design, testing, and manufacturing.

Imagine a simulator used to design cars in 2017. Like older collaborative environments, it allows engineers and project managers in different continents to work together, sometimes asynchronously, sometimes simultaneously. But what's new is the range of collaborators it brings into the design process, and the speed with which they can interact. The simulator's code base integrates features of older crash test simulators, CAD/CAM systems, and driving programs. As soon as mechanical engineers in Hiroshima upload changes to the transmission, other groups designing the engine and electrical system can see if the new design affects their systems; their changes, in turn, trigger alerts to groups working on the chassis. At the same time, test drivers in Stuttgart and Los Angeles can test drive the new design on courses that feature photo-realistic environments, in a cockpit that replicates the sound and vibration of the engine. (Because they have older designs saved, test drivers can also compare the handling and feel of the new version to its predecessors.) Finally, videos of the test drives are put on the company's Web site for car enthusiasts to review and comment on.

The U.S. military has long used simulations to train soldiers, The Unmanned Aerial Vehicle (UAV) is like a simulation in itself—pilots fly the vehicle remotely for reconnaissance and attack purposes.

Source: www.flickr.com/photos/magpie967/755871500

This, in turn, could have big consequences for companies. Creating these simulations will require collaboration between groups that today have little contact and traditionally have not had to work together in real time. The computer programmers who create crash simulations, for example, tend to work independently of the mechanical engineers who actually design cars. The new collaboration will also require developing new kinds of project management skills and techniques. Traditional project management generally seeks to break highly complex objectives into many smaller, simpler steps, which can be organized in a linear fashion. A group collaborating through simulation, in contrast, is likely to be more like a smart mob—highly interdependent, occasionally chaotic, constantly negotiating over changes, and continually playing off new ideas.

A View to a Skill: Need for Simulation-Literate Workforces

Proliferation of simulation in business will affect markets for skills. Obviously, quantitative and programming skills will be more valuable, both for creating simulations, and for understanding them. For a time, simulation literacy will give some workers an edge, much as a familiarity with personal computers offered advantages in the 1980s or early 1990s; but like computer literacy, it will eventually be taken for granted. Anyone who doesn't know how to use and learn from simulations will be at as much of a disadvantage as someone who can't read.

The growing use of simulation may have an unexpected impact on how organizations value different skills. Crisis simulation is already one of the leading edges of workplace simulation, a trend that holds across a variety of professions. In the future, as they become more common, it may be that workers who perform best in emergency simulations will gain an edge over those who "merely" do well in regular training simulations. However, this may give too much credit to risky behavior and fast reflexes, and unintentionally reduce the value of other skills that are important to organizations under regular conditions, but harder to simulate: skills such as the ability to manage complex projects, to build consensus and focus around decisions that require long-term commitment, or to respond to customer needs. In some organizations, crisis-management skills are useful for everyone to have; but organizations will need to make sure that they don't confuse what they really need with what a simulation can reveal.

us overexposed to big disasters. For example, Taleb argues that hedge funds and investment banks have developed remarkably sophisticated instruments to mitigate risk, but they prevent the smaller market corrections that would solve problems before they become unmanageably large, and encourage overconfidence by making investors think that modern financial tools give them enough foresight to avoid large downturns. As a result, they have the paradoxical effect of making financial meltdowns worse. Likewise, flood engineering and flood insurance can prevent small floods or mitigate their effects, but by encouraging builders to construct on former flood plains, ultimately leave far more people exposed to once-in-a-century disasters.

Today, such problems are found mainly in financial markets, where simulations and mathematical models are heavily used. However, as they're used more widely and constantly, it may be that simulations will encourage overconfidence in all kinds of decisions.

6 what to watch out for

Every useful tool can be misused; every instrument that extends some abilities diminishes others. It's worth asking what problems the ubiquitous, everyday use of simulation might generate.

The Uncanny Valley in Simulation

Researchers in robotics and computer games have encountered what Masahiro Mori calls "the uncanny valley." As Clive Thompson describes it, the uncanny valley is "the paradoxical point at which a simulation of life becomes so good it's bad." It's highly realistic, but lacks certain subtle details that make the whole effect feel unpleasantly artificial.

Workplace simulations will suffer from the same challenges. In some cases, this may not be much of a problem; but in others, it could skew players' or employees' behavior in negative ways. For example, police learning hostage negotiation techniques may react more aggressively to simulated kidnappers who are programmed to respond to negotiation, but whose facial expressions and body language don't adequately communicate that willingness. Rather than building calluses, officers might simply learn callousness. Given that emergencies often require nearly instinctive responses, simulations that mis-train or over-train those instincts could be counterproductive.

Misusing Predictive Models

Statistical models that accurately predict the actions of populations don't predict the behavior of individuals, yet we already tend to forget this basic fact. A recent study in the *British Journal of Psychiatry* assails the use of predictive models by government officials to make decisions about individuals. As the Guardian explains, scientists argue that when "applied to individuals the margins of error [of statistical models] are so high as to render any results meaningless."

Nonetheless, the British police and welfare agencies already use such models to spot fraudsters, health services to identify babies who might be at risk, and educators to sort out troublemakers. When these models are poured into simulations, and the results are displayed not as graphs or statistical results but in realistic-looking videos, they could become more (misleadingly) convincing.

Using Simulation to Make Things Worse

The everyday use of simulation to avoid short-term, negative outcomes may have the unintended consequence of blinding us to big disasters. Financial expert Nassim Nicholas Taleb argues that wild cards—or "black swans," as he calls them—are becoming both more frequent and more dramatic. They're becoming more frequent because of the growing interdependence of the global economy, between nations, and more frequent contact between peoples and places. They're becoming more dramatic because our ability to manage small risks creates conditions that leave

7 The Future of Reality

ONE BIG SIMULATION

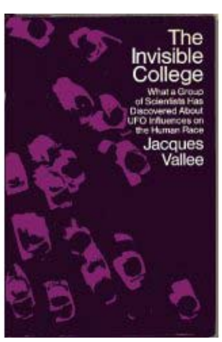
As computer simulations become more advanced, more real, and integrated into our lives, some very deep philosophical questions begin to emerge. Even at this early stage in the evolution of computer simulation, the very idea that we can simulate reality raises a profound existential question that more than a few esteemed philosophers are already grappling with: What if our reality is just a simulation running on some advanced entity's PC? Interestingly, IFTF co-founder Jacques Vallée ruminated on this very subject in the 1970s in *The Invisible College*: *What a Group of Scientists has Discovered about UFO Influences on the Human Race*. A computer scientist, Vallée framed the issue in the context of network architecture: we may be living inside a control system with a closed feedback loop, yet the operators of that system may be beyond our immediate understanding.

Famed roboticist Hans Moravec took that notion further, arguing in a 1995 *Wired* magazine interview that, "Statistically speaking, it's much more likely we're living in a vast simulation than in the original version. To me, the whole concept of reality is rather absurd. But while you're inside the scenario, you can't help but play by the rules. So we might as well pretend this is real—even though the chance things are as they seem is essentially negligible."

And most recently, Oxford philosopher Nick Bostrom published a controversial and widely publicized paper with the to-the-point title, "Are You Living In A Computer Simulation?" Like Moravec, Bostrom drew from the math world to support his theory. In short, he suggests that some future human civilization is likely running an "ancestor simulation" of human history starring, well, us. Or, as William Shakespeare famously wrote, "All the world's a stage. And all the men and women merely players."

Are we living in the Matrix? And if so, what happens if the software crashes?

IFTF co-founder Jacques Vallée explored the idea of life as a simulation in his 1975 novel *The Invisible College*.



Source: www.jacquesvallee.net

spectrum of immersion experiences

Immersion experiences, from computer simulations to play-acting, enable individuals to learn rapidly and viscerally. These low-risk learning environments allow the learner to see the world from different points of view and help improve agility and readiness. The following spectrum of immersion experiences, ranging from the most immersive for learners to the least, comes from IFTF Distinguished Fellow Bob Johansen's new book, *Get There Early: Sensing the Future to Compete in the Present* (Berrett-Koehler, 2007).

- **Simulations of reality**, where some aspect of the real world is being modeled so that it can be experienced. Simulation gaming can be an attempt to simulate a real-life situation, in order to create a low-risk learning environment within which new skills can be developed and practiced. Simulations, of course, can mislead participants or backfire if they simulate the real world inaccurately—which could give the learners a false sense of confidence. Direct simulation of the real world is very difficult in most situations, but sometimes it is possible and often even the attempt to simulate is worthwhile—even if the result does not replicate reality.
- **Alternate-reality games**, where individuals, small groups, or massive numbers of players engage in hypothetical worlds, sometimes in digital environments and sometimes in real-world settings. Alternate-reality gaming is not necessarily a simulation of anything real, but it is a compelling immersive environment with challenges—again, a low-risk world where people can learn in a first-person way. In alternative reality games, people "play" themselves in a different setting.
- **3-D immersive environments**, where people role-play an alternative identity in an online setting. There is no story and no "game" in these worlds other than what the players themselves create. For example, some young people with autism use 3-D immersive environments such as *Second Life* to practice social skills.
- **Role-play simulation games**, where learners play a role in an interactive simulation that draws from real-world experiences. The learner plays a role and is given a taste of new situations and practice with possible responses.

- **Scenarios**, where a story is brought to life. A text scenario may be more like a hypothetical case study, while a physical scenario (such as a movie ticket or some other hypothetical product from the future) is more like an artifact. The point of scenarios is to animate a forecast and engage with the users. For example, digital stories are short visual scenarios that bring aspects of a forecast to life.
- Mentoring, reverse mentoring, or shadowing, where learners are immersed for a period of time in the life of another person from whom they want to learn. For example, some corporations have used reverse mentoring to help male managers get a taste of what female managers experience, to help white managers experience what managers of color experience, and to help older managers experience what new hires experience.
- **Ad hoc immersive experiences**, where the goal is to help someone see the world from another point of view. Think of this as "anthropology light," since the goal is similar to what anthropologists would call ethnography, where a researcher immerses himself or herself in a culture to understand what is going on. Whereas an anthropologist goes deep for an extended time, an ad hoc immersive experience is just a quick taste—but it is a first-person and useful taste nonetheless. Ad hoc immersion experiences are similar to simulations, but they are much less ambitious since no imaginary world is created. An immersion is essentially an attempt to put the learner in someone else's shoes, so that they can better understand a different point of view and a different set of experiences. Special body suits have been designed with weights and awkward padding, for example, to give young people a sense of what it feels like to be inside an older body. Other special suits have been designed to give men some sense of what it is like to have a menstrual cycle.
- **Theatrical improvisation**, where actors bring a future possibility to life in a vivid way while learners watch. These experiences can be more or less elaborate, as well as more or less involving for the learners. When the actors can engage with the learners, the learning opportunities are most profound. On several occasions, I have used actors in prototype homes or stores of the future to show how consumers might use them. In a more adventurous case, I was once involved in a business event with Shakespearean actors, where we compared our ten-year forecast with the basics of human life that are similar to the time when Shakespeare was writing. Even in times of great change, many things don't change, and it is important to understand those constants in life. The event was intriguing for me, but we were not able to connect very well with the audience. Clearly, it is important to blend the medium you are using with the audience you are engaging. Even knowing the difficulties of theatrical improvisation, I think that there is great promise in using actors to bring key ideas to life. Theatrical improvisation is like role-playing where the learners don't play the roles themselves—which means they are less engaged.
- **Case studies**, where a real-world situation is described in a third-person but engaging way so that learners can become involved with the case. Case studies have a long history and much current practice in business schools (with many different approaches), so most people have become comfortable with the case as a learning method. Case studies are engaging for the students who write them, but they usually are not as engaging for the readers. You can read case studies, but you can't experience them.

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