WILLIAM CALVIN
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CLIMATE WILL CHANGE EVERYTHING

Climate will change our worldview. That each of us will die someday ranks up there with 2+2=4 as one of the great certainties of all time. But we are accustomed to think of our civilization as perpetual, despite all of the history and prehistory that tells us that societies are fragile. The junior-sized slices of society such as the church or the corporation, also assumed to outlive the participant, provide us with everyday reminders of bankruptcy. Climate change is starting to provide daily reminders, challenging us to devise ways to build in resiliency, an ability to bounce back when hit hard.

Climate may well force on us a major change in how science is distilled into major findings. There are many examples of the ponderous nature of big organizations and big projects. While I think that the IPCC deserves every bit of its hemi-Nobel, the emphasis on "certainty" and the time required for a thousand scientists and a hundred countries to reach unanimous agreement probably added up to a considerable delay in public awareness and political action.

Climate will change our ways of doing science, making some areas more like medicine with its combination of science and interventional activism, where delay to resolve uncertainties is often not an option. Few scientists are trained to think this way — and certainly not climate scientists, who are having to improvise as the window of interventional opportunity shrinks.

Climate will, at times, force a hiatus on doing science as usual, much like what happened during World War II when many academics laid aside their usual teaching and research interests to intensively focus on the war effort.

The big working models of fluid dynamics used to simulate ocean and atmospheric circulation will themselves be game-changing for other fields of dynamics, such as brain processing and decision making. They should be especially important as they are incorporated into economic research. Climate problems will cause economies to stagger and we have just seen how fragile they are. Unlike 1997 when currency troubles were forced by a big El Niño and its associated fires in southeast Asia, the events of 2008 show that, even without the boat being rocked by external events, our economy can partially crash just from internal instabilities, equivalent to trying to dance in a canoe. Many people will first notice climate change elsewhere via the economic collapse that announces it.

That something as local as a U.S. housing bubble could trigger a worldwide recession shows us just how much work we have to do in "earthquake retrofits" for our economy. Climate-proofing our financial flows will rely heavily on good models of economic dynamics, studies of how things can go badly wrong within a month. With such models, we can test candidates for economic crash barriers.

Finally, climate's challenges will change our perspective on the future. Long-term thinking can be dangerous if it causes us to neglect the short term hazards. A mid-century plan for emissions reduction will be worthless if the Amazon rain forest burns down during the next El Niño.

MICHAEL SHERMER
Publisher of Skeptic magazine, monthly columnist for Scientific American; Author, The Mind of the Market

ENERGY AND ECONOMICS: THE ROAD TO CIVILIZATION 1.0

It is January, named for the Roman God Janus (Latin for door), the doorway to the new year, and yet Janus-faced in looking to the past to forecast the future. This January, 2009, in particular, finds us at a crisis tipping point both economically and environmentally. If ever we needed to look to the past to save our future it is now. In particular, we need to do two things: (1) stop the implosion of the economy and enable markets to function once again both freely and fairly, and (2) make the transition from nonrenewable fossil fuels as the primary source of our energy to renewable energy sources that will allow us to flourish into the future. Failure to make these transformations will doom us to the endless tribal political machinations and economic conflicts that have plagued civilization for millennia. We need to make the transition to Civilization 1.0. Let me explain.

In a 1964 article on searching for extraterrestrial civilizations, the Soviet astronomer Nikolai Kardashev suggested using radio telescopes to detect energy signals from other solar systems in which there might be civilizations of three levels of advancement: Type 1 can harness all of the energy of its home planet; Type 2 can harvest all of the power of its sun; and Type 3 can master the energy from its entire galaxy.

Based on our energy efficiency at the time, in 1973 the astronomer Carl Sagan estimated that Earth represented a Type 0.7 civilization on a Type 0 to Type 1 scale. (More current assessments put us at 0.72.) As the Kardashevian scale is logarithmic — where any increase in power consumption requires a huge leap in power production — fossil fuels won't get us there. Renewable sources such as solar, wind and geothermal are a good start, and coupled to nuclear power — perhaps even nuclear fusion (instead of the fission reactors we have now) could eventually get us to Civilization 1.0.

We are close. Taking our Janus-faced look to the past in order to see the future, let's quickly review the history of humanity on its climb to become a Civilization 1.0:

Type 0.1: Fluid groups of hominids living in Africa. Technology consists of primitive stone tools. Intra-group conflicts are resolved through dominance hierarchy, and between-group violence is common.

Type 0.2: Bands of roaming hunter-gatherers that form kinship groups, with a mostly horizontal political system and egalitarian economy.

Type 0.3: Tribes of individuals linked through kinship but with a more settled and agrarian lifestyle. The beginnings of a political hierarchy and a primitive economic division of labor.

Type 0.4: Chiefdoms consisting of a coalition of tribes into a single hierarchical political unit with a dominant leader at the top, and with the beginnings of significant economic inequalities and a division of labor in which lower-class members produce food and other products consumed by non-producing upper-class members.

Type 0.5: The state as a political coalition with jurisdiction over a well-defined geographical territory and its corresponding inhabitants, with a mercantile economy that seeks a favorable balance of trade in a win-lose game against other states.

Type 0.6: Empires extend their control over peoples who are not culturally, ethnically or geographically within their normal jurisdiction, with a goal of economic dominance over rival empires.

Type 0.7: Democracies that divide power over several institutions, which are run by elected officials voted for by some citizens. The beginnings of a market economy.

Type 0.8: Liberal democracies that give the vote to all citizens. Markets that begin to embrace a nonzero, win-win economic game through free trade with other states.

Type 0.9: Democratic capitalism, the blending of liberal democracy and free markets, now spreading across the globe through democratic movements in developing nations and broad trading blocs such as the European Union.

Type 1.0: Globalism that includes worldwide wireless Internet access with all knowledge digitized and available to everyone. A global economy with free markets in which anyone can trade with anyone else without interference from states or governments. A planet where all states are democracies in which everyone has the franchise.

Looking from this past toward the future, we can see that the forces at work that could prevent us from reaching Civilization 1.0 are primarily political and economic, not technological. The resistance by non democratic states to turning power over to the people is considerable, especially in theocracies whose leaders would prefer we all revert to Type 0.4 chiefdoms. The opposition toward a global economy is substantial, even in the industrialized West, where economic tribalism still dominates the thinking of most people.

The game-changing scientific idea is the combination of energy and economics — the development of renewable energy sources made cheap and available to everyone everywhere on the planet by allowing anyone to trade in these game-changing technologies with anyone else. That will change everything.

HAIM HARARI
Physicist, former President, Weizmann Institute of Science; Author, A View from the Eye of the Storm

AT LAST: TECHNOLOGY WILL CHANGE EDUCATION

Sometimes you make predictions. Sometimes you have wishful thinking. It is a pleasure to indulge in both, by discussing one and the same development which will change the world.

Today's world, its economy, industry, environment, agriculture, energy, health, food, military power, communications, you name it, are all driven by knowledge. The only way to fight poverty, hunger, diseases, natural catastrophes, terrorism, war, and all other evil, is the creation and dissemination of knowledge, i.e. research and education.

Of the six billion people on our planet, at least four billions are not participating in the knowledge revolution. Hundreds of millions are born to illiterate mothers, never drink clean water, have no medical care and never use a phone.

The "buzz words" of distant learning, individualized learning, and all other technology-driven changes in education, remain largely on paper, far from becoming a daily reality in the majority of the world's schools. The hope that affluent areas will provide remote access good education to others has not materialized. The ideas of bringing all of science, art, music and culture to every corner of the world and the creation of schools designed differently, based on individual and group learning, team work, simulations and special aids to special needs—all of these technology enabled goals remain largely unfulfilled.

It is amazing that, after decades of predictions and projections, education, all around the world, has changed so little. Thirty years ago, pundits talked about the thoroughly computerized school. Many had fantasies regarding an entirely different structure of learning, remote from the standard traditional school-class-teacher complex, which has hardly changed in the last century.

It is even more remarkable that no one has made real significant money on applying the information revolution to education. With a captive consumer audience of all school children and teachers in the world, one would think that the money made by eBay, Amazon, Google and Facebook might be dwarfed by the profits of a very clever revolutionary idea regarding education. Yet, no education oriented company is found among the ranks of the web-billionaires.

How come the richest person on the globe is not someone who had a brilliant idea about using technology for bringing education to the billions of school children of the world? I do not know the complete answer to this question. A possible guess is that in other fields you can have "quickies" but not in education. The time scale of education is decades, not quarters. Another possible guess is that, in education, you must mix the energy and creativity of the young with the wisdom and experience of the older, while in other areas, the young can do it fast and without the baggage of the earlier generations.

I am not necessarily bemoaning the fact that no one got into the list of richest people in the world by reforming education. But I do regret that no "game-changing" event has taken place on this front, by exploiting what modern technology is offering.

Four million Singapore citizens have a larger absolute GDP than 130 million Pakistanis. This is not unrelated to all the miseries and problems of Pakistan, from poverty to terror to severe earthquake damage. The only way to change this, in the long run, is education. Nothing better can happen to the world, than better education to such a country. But, relying only on local efforts may take centuries. On the other hand, if Al Qaida can reach other continents from Pakistan by using the web, why can't the world help educate 130 million Pakistanis using better methods?

So, my game-changing hope and prediction is that, finally, something significant will change on this front. The time is ripe. A few novel ideas, aided by technologies that did not exist

until recently, and based on humanistic values, on compassion and on true desire to extend help to the uneducated majority of the earth population, can do the trick.

Am I naive, stupid or both? Why do I think that this miracle, predicted for 30 years by many, and impatiently waited for by more, will finally happen in the coming decades?

Here are my clues:

First, a technology-driven globalization is forcing us to see, to recognize and to fear the enormous knowledge gaps between different parts of the world and between segments of society within our countries. It is a major threat to everything that the world has achieved in the last 100 years, including democracy itself. Identifying the problem is an important part of the solution.

Second, the speed and price of data transmission, the advances in software systems, the feasibility of remote video interactions, the price reduction of computers, fancy screens and other gadgets, finally begin to lead to the realization that special tailor-made devices for schools and education are worth designing and producing. Until now, most school computers were business computers used at school and very few special tools were developed exclusively for education. This is beginning to change.

Third, for the first time, the generation that grew up with a computer at home is reaching the teacher ranks. The main obstacle of most education reforms has always been the training of the teachers. This should be much easier now. Just remember the first generation of Americans who grew up in a car-owning family. It makes a significant difference.

Fourth, the web-based social networks in which the children now participate pose a new challenge. The educational system must join them, because it cannot fight them. So the question is not any more: "Will there be a revolution in education?" But "Will the revolution be positive or deadly?" Too many revolutions in history have led to more pain and death than to progress. We must get this one right.

Fifth, a child who comes to school with a 3G phone, iPod or whatever, sending messages to his mother's blackberry and knowing in real time what is happening in the class room of his brother or friend miles or continents away, cannot be taught anything in the same way that I was taught. Has anyone seen lately a slide rule? A logarithmic table? A volume of Pedia other than Wiki?

At this point I could produce long lists of specific ideas which one may try or of small steps which have already been taken, somewhere in the world. But that is a matter for long essays or for a book, not for a short comment. It is unlikely that one or three or ten such ideas will do the job. It will have to be an evolutionary process of many innovations, trial and error, self adjustment, avoiding repetition of past mistakes and, above all, patience. It will also have to include one or more big game-changing elements of the order of magnitude of the influence of Google.

This is a change that will create a livable world for the next generations, both in affluent societies and, especially, in the developing or not-even-yet-developing parts of the world. Its time has definitely come. It will happen and it will, indeed, change everything.

GINO SEGRÈ
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THE EXISTENCE OF ADDITIONAL SPACE-TIME DIMENSIONS

Einstein's Theory of General Relativity, first presented in the fall of 1915, and his earlier Special Theory of Relativity have changed very little of our day to day world, but they have radically altered the way we think about both space and time and have also launched the modern theory of cosmology. If in the near future we discover additional space-time dimensions we will undergo a shift in our perceptions every bit as radical as the one experienced almost a hundred years ago.

Though proof of their existence would necessarily alter our view of the Universe, there is also a way in which our psyches would be changed. I believe we would gain a new confidence that great almost unimaginable phenomena are yet to be discovered. It would also make us realize once again the power that lies in a few simple equations, in the tools we can build to test them and in the human imagination.

At the November 6, 1919 joint meeting of the Royal Society and the Royal Astronomical Society, Sir Frank Watson Dyson reported on the observations of starlight made during the previous May's solar eclipse. "After a careful study of the plates I am prepared to say that they confirm Einstein's prediction. A very definite result had been obtained, that light is deflected in accordance with Einstein's law of gravitation." Sir John Joseph Thomson, presiding, afterwards called the result "one of the highest achievements of human thought." It was a triumphant moment for both theoretical physics and observational astronomy.

A few years after the momentous Royal Society meeting a German and a Swedish physicist, Theodor Kaluza and Oskar Klein, reached a striking conclusion. They noticed that the equations of general relativity, when solved in five rather than four dimensions, led to additional solutions that were identical to the well-known Maxwell equations of electromagnetism. Since the apparent fifth dimension had not, and still has not been observed, a necessary additional postulate for this theory to correspond to possible reality was that the fifth dimension was curled up so tightly that any motion in its direction had not been detected.

Einstein, finding this extension of his General Theory of Relativity extraordinarily attractive, tried more than once, without success, to make it part of his lifelong dream of a unified field theory of interactions. But this direction of research fell into relative disfavor during the first post World War II decades during which theoretical physics turned its attention to other matters. It returned with a vengeance during the late 1970s, gaining momentum in the 1980s as physicists began to seriously examine theories that could unite all fundamental interactions into one comprehensive scheme. The rising popularity of superstring theory, mathematically consistent only if additional space-time dimensions are present, has provided the decisive impetus for such considerations.

There are striking differences from the 1915 situation, most particularly the lack of a clear test for the detection of extra dimensions. The novel theories now in fashion do predict that additional particles must be present in nature because of these extensions of space and time, but since the mass of these particles is related to the unknown scale of the extra dimensions, it also remains unknown. Roughly speaking, the smaller the one, the larger the other. Nevertheless the hunt has begun; we are beginning to see in the literature publications from major laboratories with titles such as " Search for Gamma Rays from the Lightest Kaluza-Klein Particle", that being the name frequently given to the as of yet undiscovered particles associated with extra dimensions.

These searches are largely motivated by the desire to identify Dark Matter, estimated to be several times more plentiful in our Universe's makeup than all known species of matter. Kaluza-Klein particles are one possible candidate, perhaps hard to distinguish from other candidates even if found. Challenges abound, but the stakes are very high as well.

ED REGIS
Science Writer, Author, What Is Life?

MOLECULAR MANUFACTURING

Nothing has a greater potential for changing everything than the successful implementation of good old-fashioned nanotechnology.

I specify the old-fashioned version because nanotechnology is decidedly no longer what it used to be. Back in the mid-1980s when Eric Drexler first popularized the concept in his book *Engines of Creation*, the term referred to a radical and grandiose molecular manufacturing scheme. The idea was that scientists and engineers would construct vast fleets of "assemblers," molecular-scale, programmable devices that would build objects of practically any arbitrary size and complexity, from the molecules up. Program the assemblers to put together an SUV, a sailboat, or a spacecraft, and they'd do it—automatically, and without human aid or intervention. Further, they'd do it using cheap, readily-available feedstock molecules as raw materials.

The idea sounds fatuous in the extreme…until you remember that objects as big and complex as whales, dinosaurs, and sumo wrestlers got built in a moderately analogous fashion: they began as minute, nanoscale structures that duplicated themselves, and whose successors then differentiated off into specialized organs and other components. Those growing ranks of biological marvels did all this repeatedly until, eventually, they had automatically assembled themselves into complex and functional macroscale entities. And the initial seed structures, the gametes, were not even designed, built, or programmed by scientists: they were just out there in the world, products of natural selection. But if nature can do that all by itself, then why can't machines be intelligently engineered to accomplish relevantly similar feats?

Latter-day "nanotechnology," by contrast, is nothing so imposing. In fact, the term has been co-opted, corrupted, and reduced to the point where what it refers to is essentially just small-particle chemistry. And so now we have "nano-particles" in products raging from motor oils to sunscreens, lipstick, car polish and ski wax, and even a $420 "Nano Gold Energizing Cream" that its manufacturer claims transports beneficial compounds into the skin. Nanotechnology in this bastardized sense is largely a marketing gimmick, not likely to change anything very much, much less "everything."

But what if nanotechnology in the radical and grandiose sense actually became possible? What if, indeed, it became an operational reality? That would be a fundamentally transformative development, changing forever how manufacturing is done and how the world works. Imagine all of our material needs being produced at trivial cost, without human labor, and with no waste. No more sweat shops, no more smoke-belching factories, no more grinding workdays or long commutes. The magical molecular assemblers will do it all, permanently eliminating poverty in the process.

Then there would be the medical miracles performed by other types of molecular-scale devices that would repair or rejuvenate your body's cells, killing the cancerous or other bad ones, and nudging the rest of them toward unprecedented levels of youth, health, and durability. All without $420 bottles of face cream.

There's a downside to all this, of course, and it has nothing to do with Michael Chrichton-ish swarms of uncontrolled, predatory nanobots hunting down people and animals. Rather, it has to do with the question of what the mass of men and women are going to do when, newly unchained from their jobs, and blessed or cursed with longer life spans, they have oceans of free time to kill. Free time is not a problem for the geniuses and creators. But for the rest of us, what will occupy our idle hands? There is only so much golf you can play.

But perhaps this is a problem that will never have to be faced. The bulk of mainstream scientists pay little attention to radical nanotechnology, regarding its more extravagant claims as science-fictional and beyond belief. Before he died, chemist Richard Smalley, a Nobel prizewinner, made a cottage industry out of arguing that insurmountable technical

difficulties at the chemical bonding level would keep radical nanotechnology perpetually in the pipe dream stage. Nobody knows whether he was right about that.

Some people may hope that he was. Maybe changing *everything* is not so attractive an idea as it seems at first glance.

MAX TEGMARK
Physicist, MIT; Researcher, Precision Cosmology; Member, Scientific Directorate, Foundational Questions Institute

ACCIDENTAL NUCLEAR WAR

A serial killer is on the loose! A suicide bomber! Beware the West Nile Virus! Although headline-grabbing scares are better at generating fear, boring old cancer is more likely to do you in. Although you have less than a 1% chance per year to get it, live long enough, and it has a good chance of getting you in the end. As does accidental nuclear war.

During the half-century that we humans have been tooled up for nuclear Armageddon, there has been a steady stream of false alarms that could have triggered all-out war, with causes ranging from computer malfunction, power failure and faulty intelligence to to navigation error, bomber crash and satellite explosion. Gradual declassification of records has revealed that some of them carried greater risk than was appreciated at the time. For examples, it became clear only in 2002 that during the Cuban Missile Crisis, the USS Beale had depth-charged an unidentified submarine which was in fact Soviet and armed with nuclear weapons, and whose commanders argued over whether to retaliate with a nuclear torpedo.

Despite the end of the Cold War, the risk has arguably grown in recent years. Inaccurate but powerful ICBMs undergirded the "mutual assured destruction" stability, because a first strike could not prevent massive retaliation. The shift toward more accurate missile navigation, shorter flight times and better enemy submarine tracking erodes this stability. A successful missile defense system would complete this erosion process. Both Russia and the US retain their "launch-on-warning" strategy, requiring launch decisions to be made on 5-15 minute timescales where complete information may be unavailable. On January 25 1995, Russian President Boris Yeltsin came within minutes of initiating a full nuclear strike on the United States because of an unidentified Norwegian scientific rocket. Concern has been raised over a recent US project to replace the nuclear warheads on 2 of the 24 D5 ICBMs carried by Trident Submarines by conventional warheads, for possible use against Iran or North Korea: Russian early warning systems would be unable to distinguish them from nuclear missiles, expanding the possibilities for unfortunate misunderstandings. Other worrisome scenarios include deliberate malfeasance by military commanders triggered by mental instability and/or fringe political/religious agendas.

But why worry? Surely, if push came to shove, reasonable people would step in and do the right thing, just like they have in the past?

Nuclear nations do indeed have elaborate countermeasures in place, just like our body does against cancer. Our body can normally deal with isolated deleterious mutations, and it appears that fluke coincidences of as many as four mutations may be required to trigger certain cancers. Yet if we roll the dice enough times, shit happens — Stanley Kubrick's dark nuclear comedy "Dr. Strangelove" illustrates this with a triple coincidence.

Accidental nuclear war between two superpowers may or may not happen in my lifetime, but if it does, it will obviously change everything. The climate change we are currently discussing pales in comparison with nuclear winter, and the current economic turmoil is of course nothing compared to the resulting global crop failures, infrastructure collapse and mass starvation, with survivors succumbing to hungry armed gangs systematically pillaging from house to house. Do I expect to see this in my lifetime? I'd give it about 30%, putting it roughly on par with me getting cancer. Yet we devote way less attention and resources to reducing this risk than we do for cancer.