Apocalypse When?

Calculating How Long the Human Race Will Survive

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To Judith who encouraged me throughout this project
and
To the memory of Richard Feynman who taught me to think unconventionally

Preface

Starting about 1950, our world changed forever. Global population from then until 2000 multiplied by 2.5 and technology surged forward at an unprecedented pace. For some people these developments are a cause for great concern. Sir Martin Rees, England's present Astronomer Royal, thinks this pace may cause a fatal error within a century or two. He has wagered $1000 that a single act of bio-error or bio-terror will kill a million people before 2020. Bill Joy, co-founder of Sun Microsystems, fears that machines will overpower us using cybertechnology that he helped create. Stephen Hawking, renowned physicist and author of *A Brief History of Time*, thinks we must colonize outer space in order to ensure survival of our species.

We are already taking measures to protect ourselves from conspicuous hazards such as global warming and genetic engineering. Hence, the fatal one will most likely be some bizarre combination of events that circumvents normal safeguards. For example, mutant phytoplankton may spread across the oceans and poison the air with toxic gasses. Or a demented trillionaire may imagine God's command to exterminate humanity at all cost, and with his vast resources he may succeed. The chances of these particular hazards are minuscule, but there are hundreds more like them, so the overall risk is considerable.

Is there a way to quantify these concerns? We could build survival habitats if a numerical assessment justified the expense. The best numerical data to address this question would be survival statistics for humanoid species throughout our galaxy, especially those on Earth-like planets undergoing a technology surge. However, those data are scarce, so what else can we do?

The obvious uninspired approach would make a huge numerical model of our entire world and run thousands of simulations of our future, each with slightly different inputs and random events. Statistics of the outcomes would then indicate major threats and the probability of surviving them. Computer programs already simulate gigantic physical systems, for example, world climate. The Club of Rome has made and operated a huge numerical model of the world's economy. An essential missing piece is a numerical model for human behavior, but even that may be available in fifty years. If current trends continue, computer capability will have increased many thousandfold by then!

Would such simulations yield credible estimates of the ultimate risk? Not likely. History does not provide disasters of this magnitude to use as test cases. If it did, we could pretend to live in an earlier time and then run the program to ''predict'' events comparable to those that have actually happened. Such test runs would help us adjust parameters in the prediction program and correct flaws. In particular, the program must randomly inject rare events, tipping points, and extraordinary genius with some frequency, but that frequency must be adjusted. Otherwise, the rarities occur too often or too seldom. We might try to calibrate by using records of lesser historical disasters. However, few if any extant reports of those early disasters include enough details to initialize a simulation. Thes obstacles may be insurmuntable.

If we somehow get a credible simulation, it may indicate an urgent need for harsh reforms that offend almost everybody: levy heavy taxes on consumption of natural resources, especially fossil fuels; impose compulsory birth control; and so on. The public reaction to this report would itself make an interesting subject for a world simulation. One can imagine the repercussions: Special interests hire scientists to ridicule the world model. The simulation team is branded as alarmists trying to inflate their importance. The public is helpless because the simulation's flow chart alone is too complex for any individual to grasp. Even dedicated independent review teams would struggle long and hard with the vast number of algorithms and statistics.

# # #

The subject of this book is a more immediate and practical approach to survivability, a simple analytic model that transcends the quagmire of details. It is so simple that you can keep your daytime job and still find time to challenge it. Perhaps you can revise it using different sources of statistics.

The formulation relies on two measures of past survival: one for exposure to natural hazards, and the other for man-made hazards. The first measure is comforting. Humankind has survived natural hazards for 2000 centuries. After such long exposure, we can surely expect at least another 20 centuries, merely 1% longer. By contrast, the second measure is worrisome. Our exposure to serious man-made hazards has been a scanty half-century, which means that lack of experience leaves us vulnerable. New hazards appear faster than we can safely adapt to recently established ones.

# # #

A scholar normally has a duty to use extensive data in an effort to achieve maximum accuracy. However, human survival is an ideologically sensitive subject, and the burden of so much data might discourage constructive criticism and future revisions by others. Besides, the more analysts tinker with data, the more they must wrestle with personal prejudices that (consciously or not) could bias the results, and the greater the risk that one of their sources will be discredited, or that their analysis has (or appears to have) an ideological slant. In our curious case the reader's acceptance is more important than a modest increase in accuracy. Consequently, my analysis is simple and the input data minimal.

'Tis better to be approximate and credible than to be exact and ignored.

This tradeoff runs contrary to my training as a physicist, but that's a whole different scene. One gains credibility in physics when another laboratory independently repeats and confirms one's results. The trouble is that people won't be repeating the human extinction experiment. And by the time a forecast is verified, it is too late. Hence, in this peculiar instance, I believe that a formulation that emphasizes credibility over accuracy is justified and prudent. It is also user-friendly because a revision takes only a few sessions at a desktop computer.

The text has been written in such a way that the reader unfamiliar with math should have little trouble in following the arguments. The mathematically sophisticated reader can find a full development in the appendices.

Acknowledgments

Henri Hodara introduced me to J. Richard Gott's survival predictor, which got me hooked on this project. He also gave much useful advice, but best of all, he coined the term "Gott-erdämmerung."

Stephen Webb reviewed my manuscript and made many useful suggestions.

Richard Puetter reviewed my manuscript and found two logical errors.

Debates with Allen Ashley clarified my interpretation of Gott's predictor.

José Mata sent me his preprint about business survival and guided me to other business data.

Dale Novina edited my manuscript for style and legibility.

Trevor Lipscombe suggested the title. He and Michael Fisher made helpful suggestions.

For updates and additional statistics, go to

www.ApocalypseWhen.com

Figures

Pictures

Tables

Algebraic symbols

(appendices include some ad hoc notations)

Upper-case Roman alphabet

A	age of entity
B	bad fraction of humanity
C	constant
E	world economy
F	future time
G	Gott's survival predictor: Prob(future | age)
H	inverse of G: Prob(age | duration)
J	shortest time for hazard to act, related to gestation
K	shortest cum-risk for hazard to act, complement to
L	lost stage productions
M	pop-time of modern mankind since 1530 AD
N	number (count), various
O	quantity of oil on Planet Qwimp
P	past time
Q	prior probability of duration (at time of birth)
R	survival rank, $R = 1$ being longest duration
S	counted performances
T	entity's duration, past + future (mnemonic: term)
U	measure of hazardous economic and technical development, haz-dev
V	counted shots at shooting gallery
W	weighted probability of q, given as $W(q)$
X	population-time accrued since the dawn of humanity (mnemonic: extended)
Y	turnstile count at shooting gallery
Z	cumulative risk (hazard), cum-risk

Lower-case Roman

a	subscript for age
c	subscript for civilization
f	subscript for future
m	subscript for man-made
n	subscript for natural
p	subscript for past
p	world population
q	exponent for a Gott factor, usually paired with $1 - q$
r	exponent for a second Gott factor
s	subscript for our species

Greek

$\alpha, \beta, \ldots, \omega$	series of exponents totaling 1.0
λ	hazard rate
Λ	initial (now) hazard rate to our species, used with subscripts s and c; see above
μ	feedback exponent for haz-dev U
ω	exponent for converting pop-time (X) to haz-dev (U) and cum-risk (Z)

Abbreviations and acronyms

AIDS	Acquired Immune Deficiency Syndrome
BP	Billion People
BPC	Billion People-Centuries
BSE	Bovine Spongiform Encephalopathy
GDP	Gross Domestic Product
GA	Genetic Algorithm
GSP	Gott's Survival Predictor
GWP	Gross World Product
NASA	National Aeronautics and Space Administration
NSE	Natural Sciences and Engineering
pdf	probability density function
SES	Secret Eugenics Society
SEC	Securities and Exchange Commission
TPY	Tera-People-Years (tera = trillion)

About the author

Dr. Wells holds a Ph.D. in physics with a minor in mathematics from the California Institute of Technology (Caltech), where his mentor was Prof. Richard Feynman, Nobel Laureate. Wells worked at Caltech's Jet Propulsion Laboratory where he analyzed the unexpected tumbling of Explorer I satellite. This led to an improved design for later Explorers. He was co-inventor of a mechanism that stops a satellite's spin after it attains orbit. This device was used in several missions during the early years of the space program. He then founded and led the Quantum Electronics Group.

Dr. Wells spent most of his career as chief scientist of Tetra Tech Inc., an engineering firm doing research and development under contract to clients, mostly military. He is now Chief Scientist Emeritus of L-3 Photonics in Carlsbad, California and a member of San Diego Independent Scholars.

Introduction

It's a poor sort of memory that only works backwards.
—Lewis Carroll

The great mathematician John von Neumann (1903–57) once famously said, "The ever accelerating progress of technology . . . gives the appearance of approaching some essential singularity [an abnormal mathematical point] in the history of the race beyond which human affairs, as we know them, could not continue." Another math professor, Vernor Vinge, well known for his science fiction, picked up the concept. He began lecturing about the *Singularity* during the 1980s and published a paper about the concept in 1993 [1].

The ideas caught the imagination of non-scientists who founded a secular moral philosophy in 1991. They call themselves "Singularitarians" and look forward to a technological singularity including superhuman intelligence. They believe the Singularity is both possible and desirable, and they support its early arrival. A related philosophy is called *transhumanism*, followers of which believe in a *post-human* future that merges people and technology via bioengineering, cybernetics, nanotechnologies, and the like.

By contrast, a number of renowned scientists think that the advent of the Singularity is a time of great danger. The pace of technological innovation is accelerating so rapidly that new waves of progress appear faster than we can safely acclimate to other recently established ones. Sooner or later we shall make a colossal mistake that leads to apocalypse. The killer need not be a single well-known hazard like global warming. Scientists who are alert to this sort of threat are watching indicators for signs of danger and will likely warn us before the hazard becomes critical. Instead, the killer will likely be something we overlook, perhaps a complex coincidence of events that blindsides us. Or it may be a devious scheme that a

Entrance to the Svalbard Global Seed Vault.

misanthrope conceives, somebody with the mentality of the hackers who create computer viruses.

Sir Martin Rees, England's current Astronomer Royal, thinks the 21st century may be our last [2], the odds being about 50–50. He has wagered $1000 that a single act of bio-error or bio-terror will kill a million people by 2020.

Perhaps the most gravely worried is Bill Joy, co-founder of Sun Microsystems and inventor of the Java computer language. He contributed much to the cyber-technology that he now fears [3]: "There are certain technologies so terrible that you must say no. We have to stop some research. It's one strike and you're out." Again, "We are dealing now with technologies that are so transformatively powerful that they threaten our species. Where do we stop? By becoming robots or going extinct?"

Physicist Stephen Hawking, renowned author of *A Brief History of Time*, has joined the chorus: "Life on Earth is at the ever-increasing risk of being wiped out by a disaster, such as sudden global warming, nuclear war, a genetically engineered virus, or other dangers we have not yet thought of." To my knowledge no eminent scientist has publicly objected to any of these concerns.

In June 2006 the five Scandinavian prime ministers gathered at Spitsbergen, a Norwegian island in the far arctic, part of the Svalbard archipelago. The occasion was the groundbreaking ceremony to begin construction of a $5-million doomsday vault that will store crop seeds in case of a global calamity. Again, prominent people have a vague but widespread perception of serious danger.

Optimists disagree including the late economist Julian Simon [4] and the late novelist Dr. Michael Crichton [5]. Crichton has reviewed past predictions of doom and, from their failure, he has inferred that all such predictions are invalid. This is clearly a *non sequitur* since all prophecies of doom fail—except the last.

All these pundits, both optimists and pessimists, rely on qualitative reasoning that is endlessly debatable. By contrast, the arguments presented here are quantitative. Numerical results are also debatable, but to a lesser extent. Doubts converge on two parameters. I hope that readers will use this model, and with modest effort and different sources of data compute their own survival figures. Detailed results will vary, but the most robust conclusions will prevail.

\# # #

Some folks question whether it is valid to apply an impersonal mathematical formula to human survival, given that we are intelligent conscious creatures with ideals and spiritual qualities. To answer this objection, we can represent humanity by microcosms for which actual survival statistics are readily available. In particular, business firms and theatrical productions share important qualities with humanity. Those two microcosms plus humanity comprise three entities with the following attributes in common:

- All three consist of people striving for the entity's survival.
- All are exposed to many diverse hazards.
- All are aggregates of individuals, each of whom can be replaced while the entity remains intact.
- Within each entity the individuals act from mixed motives that balance group interests against personal ones.
- None of the three entities (our species, business firms, stage productions) has a cutoff age, a maximum it cannot exceed.

However, there is one relevant difference. People in businesses and in theater work together for the common good and develop a sense of teamwork and group consciousness. This does not extend to our species as a whole, which is too vast and amorphous for such feelings to take hold. With regard to cooperation, our species as a whole is the *least* "human" of the three entities. Therefore we might expect our species to conform *better* to a dispassionate, indifferent formula than the "more human" microcosms do.

Shakespeare would approve of stage plays as a microcosm for human survival: "All the world's a stage, and all the men and women merely players. They have their exits and their entrances" (*As You Like It*, 2:7).

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Technology, industry, and population, all feed on one another to produce a dangerous level of development. Bulldozers raze jungles to expand agriculture. Machinery plows the land, plants crops, and harvests them. The abundant food then promotes population, more people to make more machines to produce still bigger crops. This so-called *positive feedback* runs faster and faster. Agrochemistry produces fertilizer and insecticides, which make more food followed by more people, who consume more fertilizer and insecticides and deplete natural resources. People work in sweatshops and make more computers, which free our time to build more industry and invent more technology. The processing power of computers doubles every few years. Everything will accelerate until civilization hits some hard physical limit and breaks down. The human race may be part of that breakdown.

All these survival risks are far too complex and chaotic to analyze directly. We cannot attempt to extrapolate current trends. That would be valid only briefly until our world encounters a *tipping point*. After that, trends change suddenly, drastically and unpredictably. The study of such instability is known as *chaos* or *complexity theory*. The best-known paradigm of chaos is the proverbial butterfly in Brazil that can cause (or prevent) a tornado in Texas if it decides to flit from one twig to the next. The butterfly's tiny slipstream encounters an unstable airflow and alters its motion out of proportion to its original size. These secondary currents in turn alter bigger instabilities, and so on until the train of events grows to hurricane size.

Such bizarre causality applies to each single instance. However, in the statistics of many tornadoes and many butterflies, the number of times a butterfly causes a tornado offsets the number of times another butterfly prevents one. Thus, for big samples, the number of tornadoes and butterflies are unrelated on average, as you would expect. In other words, statistical numbers conform to smooth predictable formulas despite the chaos in particular instances.

Imagine living in 1900 and trying to anticipate nuclear winter, cobalt bombs, and global warming. Such predictions were impossible then and are just as impossible now. Therefore, our formulation for studying long-term human survival is not based on numerical simulations of future events or on any detailed risk analysis. Instead, it transcends these imponderables by relying on humanity's two-part track record for survival: one part is past exposure to natural hazards, and the other is past exposure to man-made hazards.

A rough analogy may help here. Suppose you measure the overall properties of a big machine—inputs and outputs such as power consumption, power delivered, temperature, pressure, and entropy. Then you apply the laws of thermodynamics to the machine as a whole and deduce something about its performance without analyzing all the forces on individual gears and wheels. In principle the detailed analysis would convey more information, but in practice it may be inaccessible, too costly, impractical and/or prone to error. Likewise we put aside the details of world simulation and rely instead on humanity's dual histories of survival.

Our track record for surviving natural hazards is comforting. Humankind has survived them for 2000 centuries. After such long exposure, we can surely expect to survive another 20 centuries, only 1% longer, other things being equal. But other things are not equal. Our exposure to serious man-made hazards has lasted a scanty half century. New hazards appear faster than we can safely acclimate to established hazards. Our job is to balance this huge disparity in exposure and arrive at a best estimate for our species' longevity.

Had we known our species' age in 1900, only the first survival history would apply, the one for natural hazards. In that case, as we shall see, the formula from this book reduces to a simpler formula first discovered by astrophysicist J. Richard Gott [6]. Imagine that you were living in 1900 and discovered Gott's formula. Using it, you would have predicted a 90% chance of survival for at least another 22,000 years—nothing to be concerned about.

For comparison, our ancestor, *Homo erectus*, lasted 1.6 million years—8 times longer than our current age. Our cousins, the Neanderthals, lasted 300,000 years—