

Lessons from Covid-19: Efficiency vs Resilience

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Self-Introduction

- ◆ Grew up on a kibbutz in Israel
- ◆ Age 10: "The Young Technologist"
- ◆ Rabbinical path -> scientific path
- ◆ 2006: SW offshoring study
- ◆ 2007-2017: CACM EIC
- ◆ 2012 -- : Computing and society



COVID-19: Public-Health Crisis

6/9/2020 Coronavirus Update (Live): 7,189,803 Cases and 408,240 Deaths from COVID-19 Virus Pandemic - Worldometer

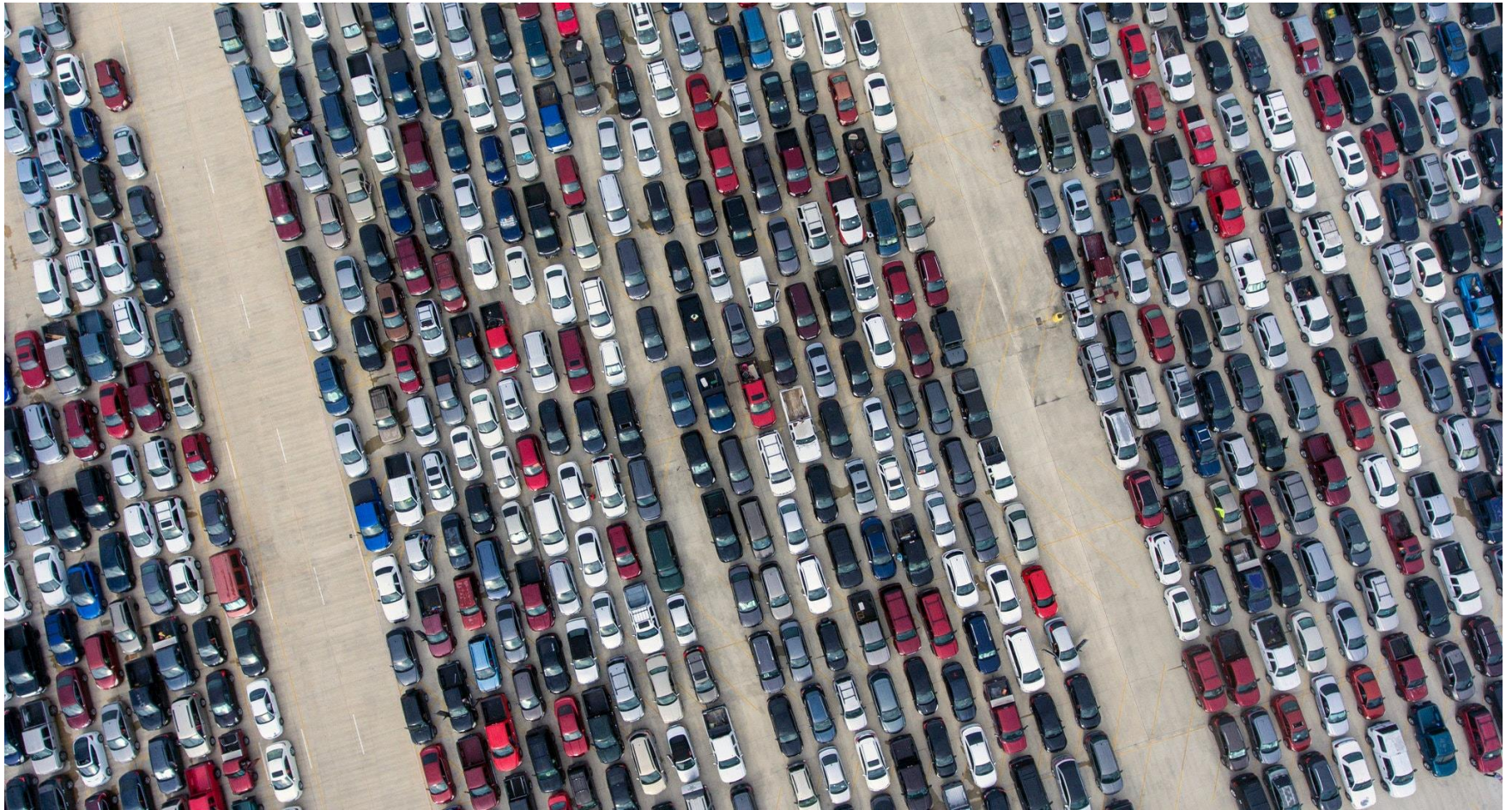
Now Yesterday 2 Days Ago

Columns ▾

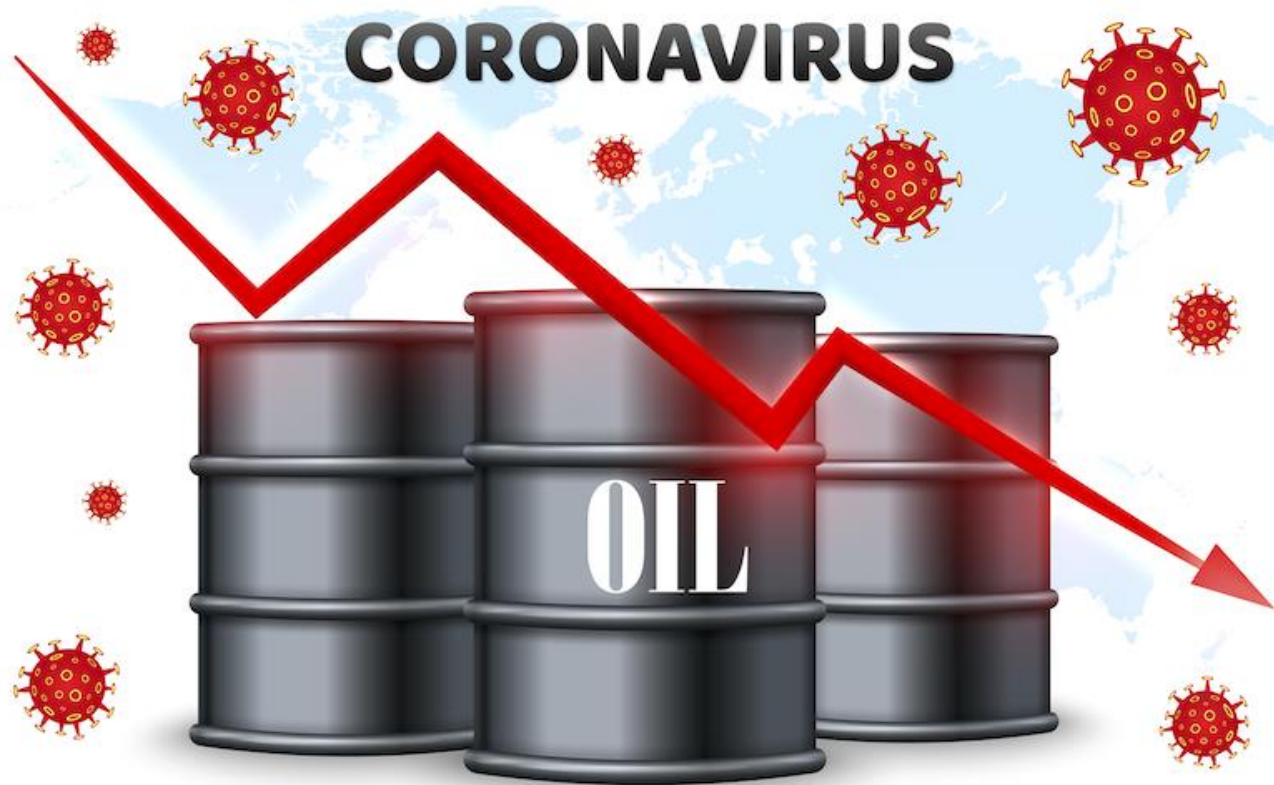
Search:

All Europe North America Asia South America Africa Oceania											
#	Country, Other	Total Cases	New Cases	Total Deaths	New Deaths	Total Recovered	Active Cases	Serious, Critical	Tot Cases/ 1M pop	Deaths/ 1M pop	Total Tests
	World	7,189,803	+107,205	408,240	+3,157	3,530,751	3,250,812	53,798	922	52.4	
1	USA (country/us/)	2,026,428	+18,979	113,055	+586	772,007	1,141,366	16,907	6,124	342	21,6
2	Brazil (country/brazil/)	710,887	+18,925	37,312	+813	325,602	347,973	8,318	3,346	176	9
3	Russia (country/russia/)	476,658	+8,985	5,971	+112	230,688	239,999	2,300	3,266	41	13,0
4	Spain (country/spain/)	288,797	+167	27,136		N/A	N/A	617	6,177	580	4,4
5	UK (country/uk/)	287,399	+1,205	40,597	+55	N/A	N/A	516	4,235	598	5,7
6	India (country/india/)	265,928	+8,442	7,473	+266	129,095	129,360	8,944	193	5	4,7

COVID-19: Economic Crisis



COVID-19: Energy Crisis



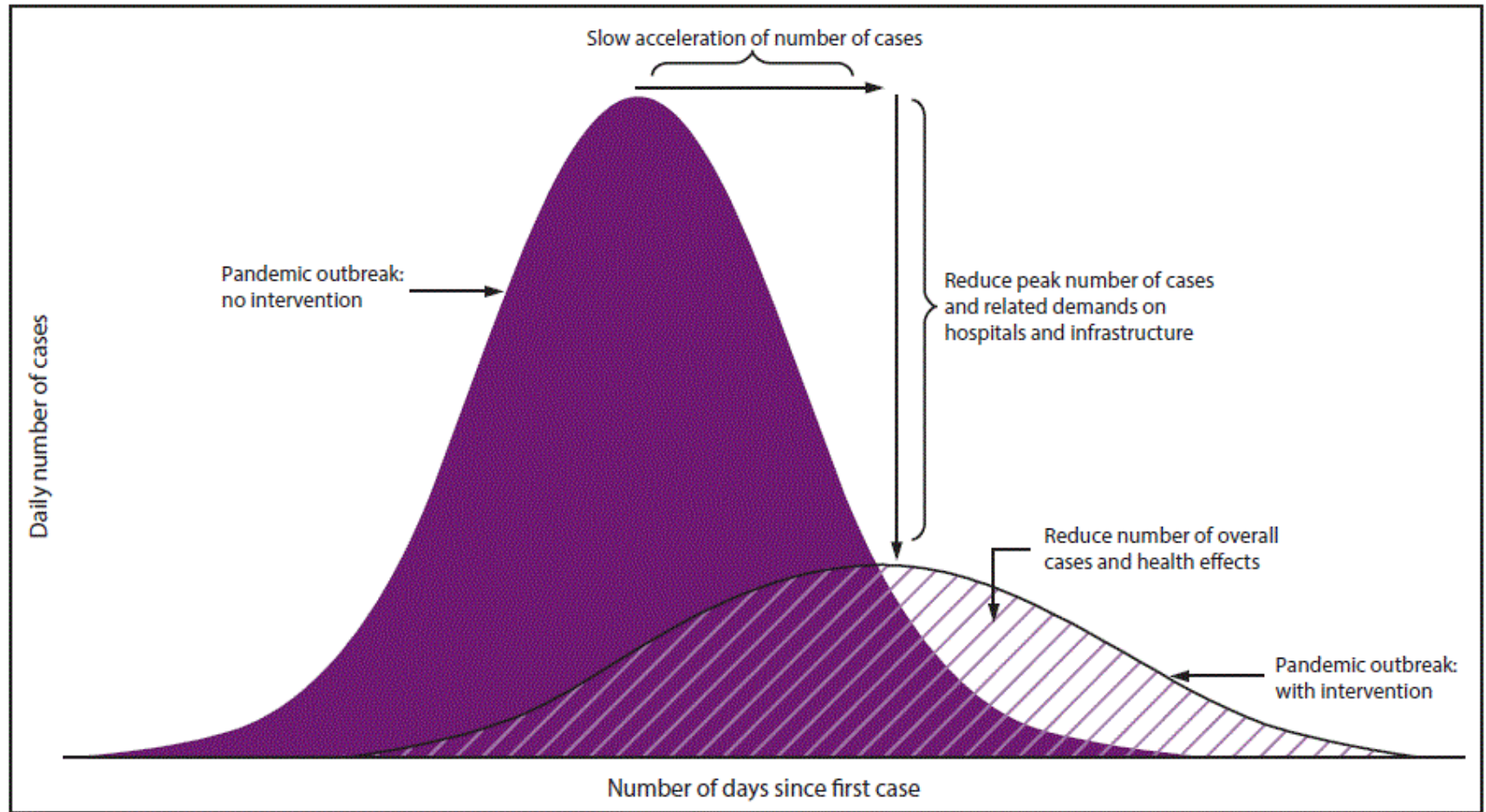
COVID-19: Social Crisis



COVID-19: Political Crisis



March'20: Flattening the Curve



Why Flatten the Curve?

- ◆ Many hundreds of thousands of infections will happen — but they don't all have to happen at once!
- ◆ *MarketWatch, April 2020*: "Nurses are wearing garbage bags as they battle coronavirus: 'It's like something out of the Twilight Zone'"



Resilience vs Efficiency

- ◆ *William Galston, WSJ, March 2020: Efficiency Isn't the Only Economic Virtue*
 - *"What if the relentless pursuit of efficiency, which has dominated American business thinking for decades, has made the global economic system more vulnerable to shocks?"*
 - *"Efficiency comes through optimal adaptation to an existing environment, while resilience requires the capacity to adapt to disruptive changes in the environment."*

Resilience: ability to recover readily from illness, depression, adversity, or the like

How We Broke the World

- ◆ *Thomas Friedman, NYT, May 30, 2020: Greed and globalization set us up for disaster.*
 - *Over the past 20 years, we've been steadily removing man-made and natural buffers, redundancies, regulations and norms that provide resilience and protection when big systems — be they ecological, geopolitical or financial — get stressed.*
 - *We've been recklessly removing these buffers out of an obsession with short-term efficiency and growth, or without thinking at all.*

On the Inefficiency of Being Efficient

M.A. Goldberg, *Environment and Planning*, 1975:
"Decision making in the industrialized nations of the western world increasingly can be characterized by its scale and speed of implementation. *Another facet of decision making is the narrowness with which problems are defined and the equally narrow range of alternatives sought for solution.* This paper documents these elements of decisions and also sketches out a number of scenarios where such an approach has led to unexpected, and often undesirable, consequences."

Example: Just-in-Time

- ◆ **JIT Manufacturing:** *a methodology aimed primarily at reducing times within the production system as well as response times from suppliers and to customers.*
 - Reduce inventory costs by reducing inventory.
 - Parts should arrive "just in time".
- ◆ JIT manufacturing is highly efficient, but assumes *best-case logistics.*
 - *Efficiency at the expense of resilience.*

Why Are There Still Not Enough Paper Towels?

Sharon Terlep + Annie Gasparro, WSJ, Aug. 2020: "Blame lean manufacturing. A decades-long effort to eke out more profit by keeping inventory low left many manufacturers unprepared when Covid-19 struck. And production is unlikely to ramp up significantly any time soon."



Why Did Covid Overwhelm Hospitals?

Russell Gold Terlep +Melanie Evans, WSJ, Sept. 2020: Why Did Covid Overwhelm Hospitals? A Yearslong Drive for Efficiency!

- "Health systems have kept a tight rein on employee numbers and expanded outpatient care, helping their finances but making them less prepared for a medical crisis."

The Formula That Killed Wall Street

- ◆ Value at risk (VaR) is a measure of the risk of loss for investments. It estimates how much a set of investments might lose (with a given probability), given normal market conditions, in a set time period such as a day.

- ◆ David X. Li: Gaussian Copula Function:

$$\Pr[T_A < 1, T_B < 1] = \Phi_2(\Phi^{-1}(F_A(1)), \Phi^{-1}(F_B(1)), \gamma)$$

- ◆ Formula did not give good estimates during abnormal market conditions, e.g., the 2008 Financial Crash.

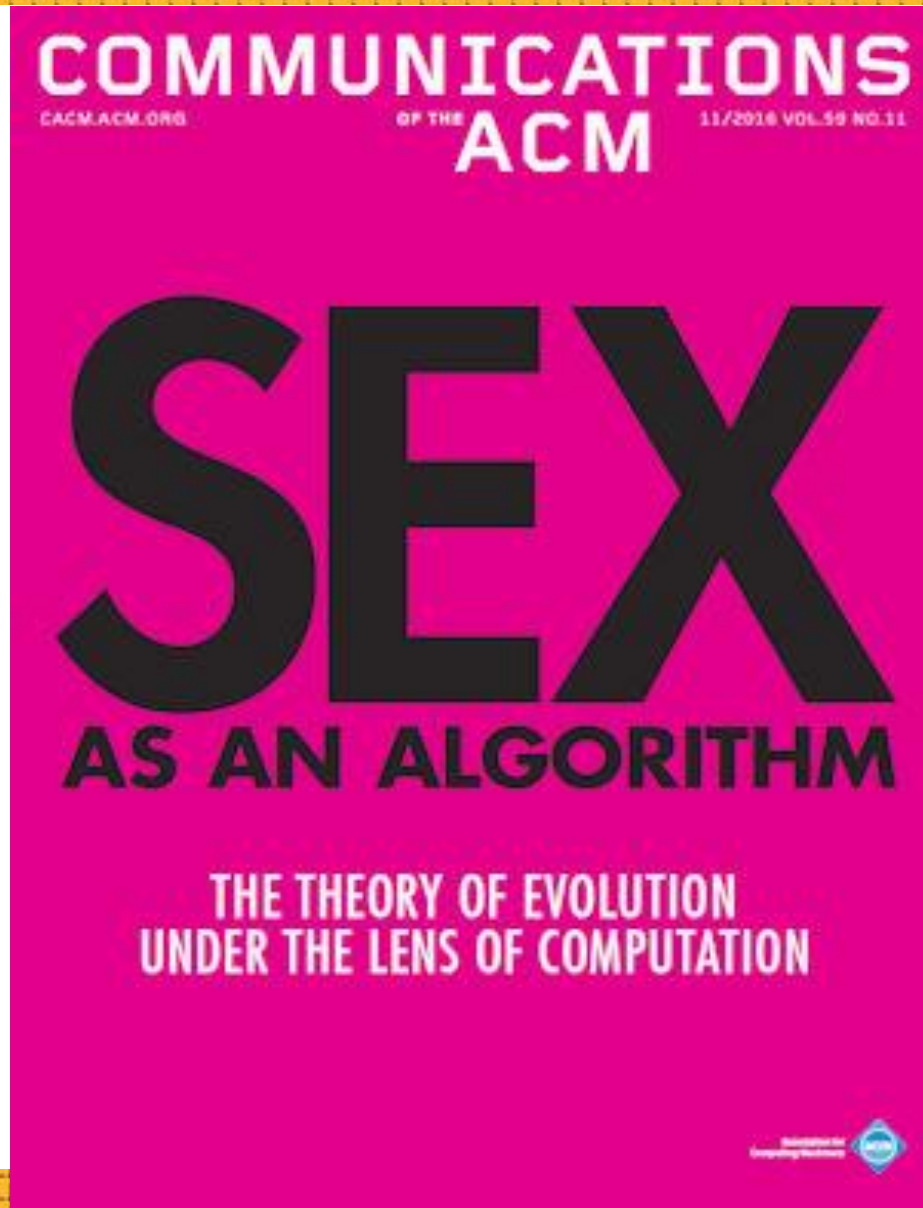
Efficiency vs Resilience in Governance

- ◆ *Winston S. Churchill, 1947: "Many forms of Government have been tried, and will be tried in this world of sin and woe. No one pretends that democracy is perfect or all-wise. Indeed it has been said that democracy is the worst form of Government except for all those other forms that have been tried from time to time."*
- ◆ **Democracy:**
 - *Highly inefficient*
 - *Generally, more resilient than other forms of governments*
 - **But:** *democracy and pandemics?*

Resilience vs. Precarity

- ◆ ***The Secret Shame of Middle-Class Americans:*** Nearly half of Americans would have trouble finding \$400 to pay for an emergency. (*The Atlantic, May 2016*)
- ◆ ***American Living on the Financial Edge:*** Two-third of Americans would have trouble immediately paying an unanticipated bill of \$1,000 (*Associated Press, May 2016*)
- ◆ ***Adam Serwer, The Atlantic, June 2020: It Didn't Have to Be Like This*** - "The desperation of US workers in the aftermath of the coronavirus was the product of a series of policy decisions and missed opportunities."

Resilience and Efficiency in Nature



Sex as an Algorithm, I

- ◆ A. Livnat and C. Papadimitriou, *CACM*, 11/2016:
 - Computational experience has shown that *Simulated Annealing*, which is a local search—via a sequence of small mutations—for an optimal solution, is, in general, superior computationally to *Genetic Algorithms*, which mimic sexual reproduction and natural selection.
 - Why then has nature chosen sexual reproduction as almost the exclusive reproduction mechanism in animals?

Sex as an Algorithm, II

- ◆ A. Livnat and C. Papadimitriou, *CACM*, 2016:
 - Sex as an algorithm offers advantages other than good performance in terms of approximating the optimum solution.
 - In particular, sexual reproduction favors genes that work well with a greater diversity of other genes, and this makes the species more adaptable to disruptive environmental changes, that is to say, *more resilient*.

Efficiency & Resilience as Optimization

- ◆ **Efficiency:** Short-term optimization
- ◆ **Resilience:** Long-term optimization

- ◆ Nature prefers long-term to short-term optimization
 - **Why? *Survival!***
 - **Example: Dinosaurs**

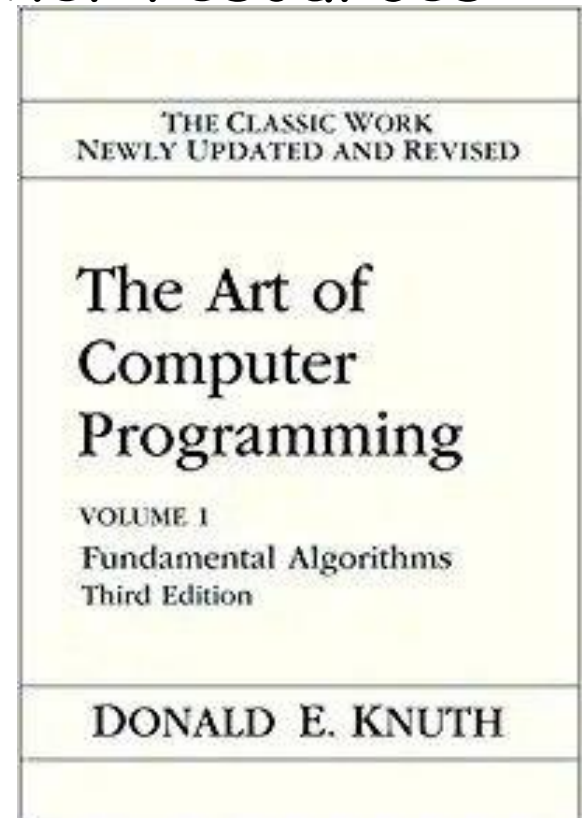


Reverse Engineering of Biological Complexity

- ◆ Marie E. Csete and John C. Doyle, *Science*, 2002: "*Net fragility is a conserved quantity.*"
 - **Fragility**: antonym of robustness
 - **V. Kumar**: If you optimize for faster time scales, you will lose in larger time scales.

Efficiency vs Resilience in Computing

- ◆ **Wikipedia:** "In computer science, the *analysis of algorithms* is the process of finding the computational complexity of algorithms—the amount of time, storage, or other resources needed to execute them."
 - It's all about *efficiency*!



Example: Sorting

- ◆ Sorting algorithms:
 - BubbleSort: $WC = O(n^2)$, $AC = O(n^2)$
 - MergeSort: $WC = O(n \log n)$
 - QuickSort: $WC = O(n^2)$, $AC = O(n \log n)$
- ◆ David H. Ackley, CACM, 2013: What about robustness?
 - Comparison errors: random on 10% of inputs
 - BubbleSort is robust, MergeSort and QuickSort are not!
 - **Key: Redundant** comparisons!

Example: PageRank

- ◆ **PageRank** is an algorithm used by Google Search to rank web pages in their search engine results. PageRank was named after Larry Page, one of the founders of Google. PageRank is a way of measuring the importance of website pages.
- ◆ PageRank works by counting the number and quality of links to a page to determine a rough estimate of how important the website is. The underlying assumption is that more important websites are likely to receive more links from other websites.

Search-Engine Optimization

- ◆ *Search engine optimization (SEO)* is the process of growing the quality and quantity of website traffic by increasing the visibility of a website or a web page to users of a web search engine.
- ◆ In other words: PageRank *is not resilient*.
- ◆ Today:
 - The PageRank patent has expired.
 - Google's search-result-ranking algorithm is a trade secret.

Probably Approximately Correct

- ◆ *Stockmeyer's PAC Computing (1983)*: A randomized algorithm computes a function approximately. The goal is that, with high confidence, the approximate results will have low error.
- ◆ **Parameters**: error - ϵ , confidence - δ
- ◆ **Omission**: What happens with probability $1-\delta$?
- ◆ *Chakraborty, Meel, and Vardi, 2016*: SPAC -- Result should also be correct in **expectation!**
 - **Resilience!**

Friction in Computing

- ◆ *MYV, CACM, 2013*: "Our discipline is dedicated to *reducing friction*. Latency must be eliminated, bandwidth must increase, and ubiquity should be universal. Our goal is to reduce the friction of computing and communication as much as possible."
- ◆ Facebook's CEO Mark Zuckerberg speaks of "*frictionless sharing*" as a goal!
- ◆ We now know that the "utopia" of frictionless sharing leads to filter bubbles, fake news and extreme content.

The Flash Crash

- ◆ On 5/6/'10, 2:45 P.M., the U.S. stock market declined steeply, with the DJIA plunging about 600 points in five minutes. U.S. SEC and CFTC identified high-frequency trading as the cause of the crash.
- ◆ Proponents of high-frequency trading say it helps make the markets more "liquid."
- ◆ **Thomas Peterffy**, a high-frequency trading pioneer: *"Today's drive for speed has absolutely no social value."*
- ◆ **E. Budish, P. Cramton, J. Shim, 2015**: *"The high-frequency-trading arms race is a symptom of flawed market design."*

Tinder's Frictionless Dating

- ◆ Jenna Birch, WaPo, 2018: Why is it so hard to turn a Tinder date into a relationship?
- ◆ "Despite the swarms of matches over the years, I've never had an app date turn into an actual relationship."
- ◆ MSU Study: Couples who meet online are 28% more likely to split up within one year.
- ◆ The efficiency of Tinder dating *lowers* expectations by both parties - "Easy comes, easy goes."



Frictionful Computing

- ◆ Imagine a mechanical engineer who declares that her goal is to eliminate *all* friction, period. We would view this as *insane*.
- ◆ The world cannot function without friction. The goal should be to have the right amount of friction, in the right place, in the right time.
- ◆ Yet computer science seems committed to the total elimination of friction in computing.
- ◆ *Plea: Welcome back friction in computing!*

CEO Software

- ◆ *David H. Ackley, CACM, 2013: Beyond Efficiency -- Esteem for efficiency should be tempered with respect for robustness.*
 - *A common perspective says software designers and programmers should assume a 100% reliable deployment platform, and the goal of software is 'CEO': Correctness and Efficiency Only.*
 - *It would help to have better visibility into efficiency-robustness trade-offs. Existing software quality metrics could be expanded to include correctness degradation under various fault models.*

System Failure

AI Spector, 10/'20:

- ◆ Boeing 737 Max has a data-centric control loop to overcome some flight instability due to the retrofitting of very powerful and efficient engines into the older airframe.
- ◆ Design proved susceptible to the malfunction of *just one sensor*. The result were two horrific crashes and years of aircraft grounding.
- ◆ In retrospect, the engineers *overly optimized for fuel economy and time to market at the expense of safety*.

Security Last

A view from the security trenches: "First, somebody builds a thing. And it's super useful. Then eventually somebody else comes along and finds a vulnerability. Then security becomes a part of the engineering process. Just like we need to make sure our code doesn't have bugs that make it crash, we also need to make sure that our code doesn't have bugs that can be exploited for bad purposes. Turn the crank for enough years, and eventually security gets better."

Recent example: Zoom

The State of Cyberinsecurity

- ◆ So here we are, 75 years into the computer age and after four ACM Turing Awards in the area of cryptography (but none in **cybersecurity**), and we still do not seem to know how to build secure information systems.
- ◆ The risk is no longer merely about compromised privacy. We must worry now about the **integrity of vital infrastructure components**.
- ◆ And yet, *the computing community marches forward with no special sense of urgency.*

Cyber Libertarianism

- ◆ Over the past 100 years, the amount of vehicle miles traveled has been steadily increasing, but fatalities with respect to vehicle miles traveled have been decreasing.
- ◆ U.S. Congress established the National Transportation Safety Board in 1926. Why is there no National Cyber Security Board?
- ◆ Cyber libertarianism is a common attitude in the tech community: "*regulation stifles innovation*".
- ◆ Tech has not been able to address the cybersecurity situation on its own; IMHO, it is time to get governments involved.

Back to Economic Efficiency

- ◆ The relentless pursuit of efficiency prevented us from investing in getting ready for a pandemic, in spite of many warnings over the past several years, and pushed us to develop a global supply chain that is quite far from being resilient.
- ◆ **Feb. 27, 2020:** President Trump defends huge cuts to the CDC's budget by saying the government can hire more doctors "when we need them" during crises.

Economic Efficiency

- ◆ *Economic efficiency* means goods and factors of production are distributed or allocated to their most valuable uses and waste is minimized.
- ◆ Free-market advocates argue that through individual self-interest and freedom of production as well as consumption, economic efficiency is achieved and the best interest of society, as a whole, are fulfilled.
- ◆ Does efficiency guarantee optimality?

“First Welfare Theorem”

FWT: Under certain assumptions, a free market will tend toward a competitive, Pareto-optimal equilibrium.

In other words: Free markets produce economic efficiency.

Question: How well does such an equilibrium serve the best interest of society?

Price of Anarchy

- ◆ **Koutsoupias+Papadimitriou, 1999:** Use the ratio between the worst possible Nash equilibrium and the social optimum as a measure of the “price of anarchy” in free markets.
 - *The price of anarchy can be arbitrarily high, depending on the complexity of the system.*
- ◆ **In other words:** *Economic efficiency does not guarantee the best interests of society, as a whole, are fulfilled!*

Reaching Equilibria

- ◆ Daskalakis, Goldberg, and Papadimitriou, 2005: How long it takes until economic agents converge to an equilibrium?
 - *There are systems in which convergence to mixed Nash equilibria can take an exceedingly long time.*
- ◆ In other words, markets are very unlikely ever to be in an equilibrium, because the underlying variables, such as prices, supply, and demand are very likely to change during slow convergence.
- ◆ **So: No efficiency and no optimality!**

Greed is Good?

- ◆ In the 1987 movie *Wall Street*, Michael Douglas as Gordon Gekko gives a speech where he said, "*Greed, for lack of a better word, is good!*"
 - **Argument:** Adam Smith's "Invisible Hand"
- ◆ **But:** Every senior CS student knows that greedy algorithms get stuck in local optima. A systemic intervention is needed to drive them out of such optima.
- ◆ **Question:** How do we get out of the "local optimum" of cyber security? ***Market failure!***

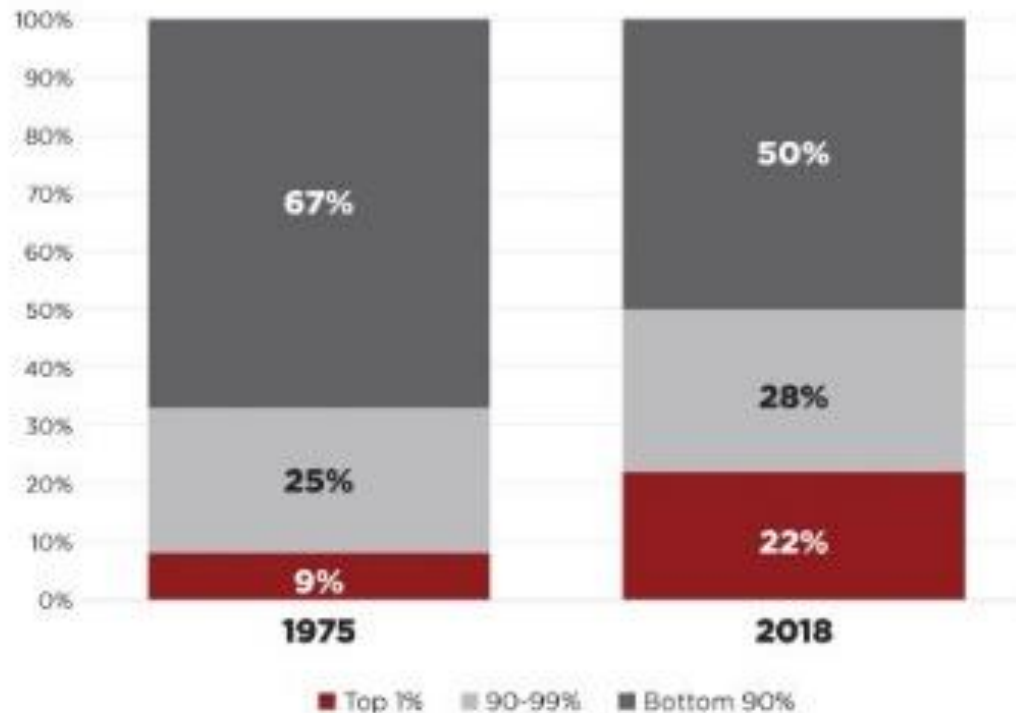
“Greed is Good, Except When It is Bad!”

- ◆ **Marc Benioff, Salesforce, 9/'20:** “I didn't agree with Friedman then, and the decades since have only exposed his myopia. Just look where the obsession with maximizing profits for shareholders has brought us: terrible economic, racial and health inequalities; the catastrophe of climate change. It's no wonder that so many young people now believe that capitalism can't deliver the equal, inclusive, sustainable future they want.”

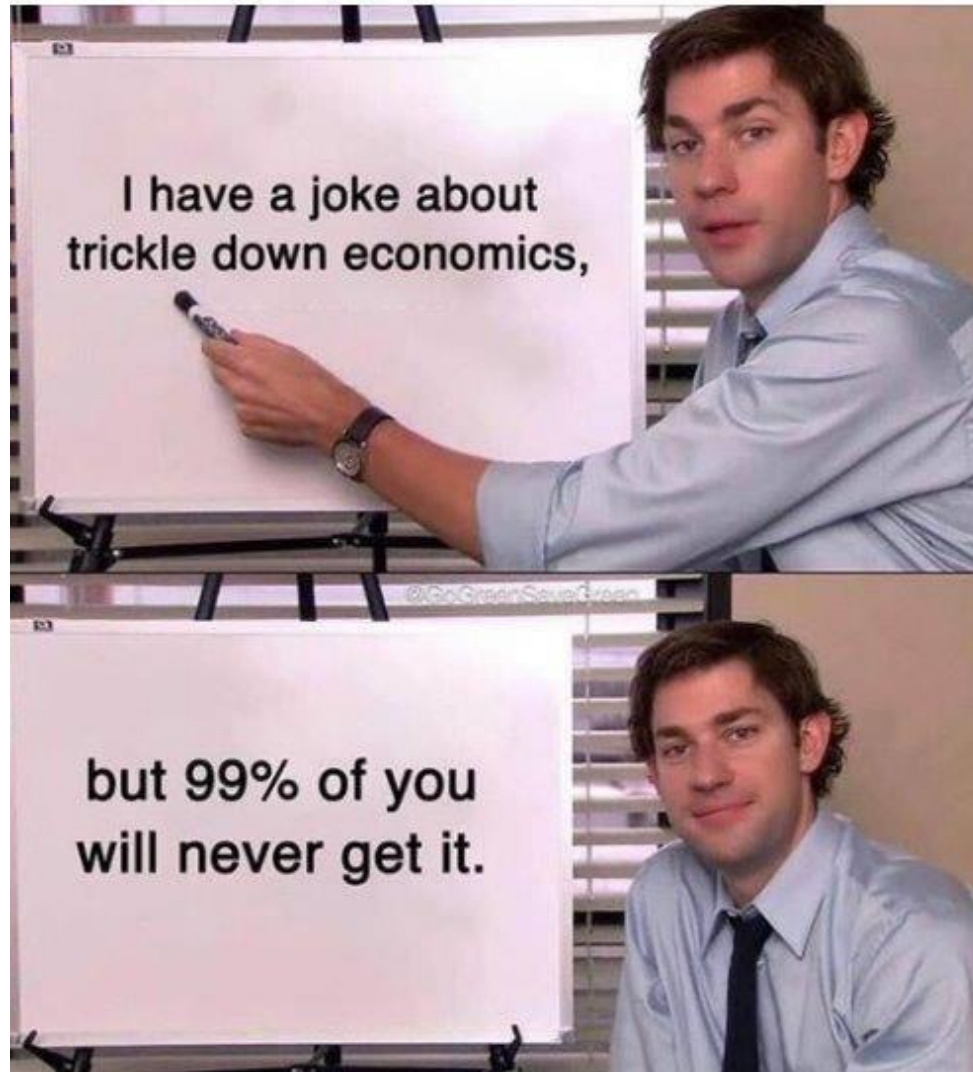
Wealth Transfer

- ◆ Nick Hanauer and David M. Rolf, *Time*, 9/'20: "The Top 1% of Americans Have Taken \$50T From the Bottom 90%."

Figure 2. Distribution of Taxable Income for 1975 to 2018



Trickle-Down Economics



Homo economicus

- ◆ The portrayal of humans as agents who are consistently rational, narrowly self-interested, and who pursue their subjectively-defined ends optimally.
- ◆ Behavioral economics examines cognitive biases and other irrationalities as well as bounded rationality (Kahneman, Trevrsky, et al.)
- ◆ H.A. Simon, 1956: *Satisficing* - settling for a good-enough outcome
 - *Less efficient, more resilient!*

Optimizing DS Games

- ◆ **Discounted-Sum Games with Rewards:**
 - Two strategic players (0 and 1)
 - State-based rewards
 - Discounted-sum aggregation
- ◆ **Optimization Problem:** Find strategy for 0 that maximize reward against 1's strategies.
- ◆ **Zwick-Patterson, 1996:** PolyTime value-iteration algorithm for optimization problem.

Resilient Optimal DS Games

- ◆ Discounted-Sum Games with Rewards
- ◆ Optimization Problem: Find strategy for 0 that maximize reward against 1's strategies.
- ◆ Subject to: temporally extended goals
 - E.g.: *Every message sent is eventually received.*
- ◆ Chatterjee et al., 2017: no optimal strategy!

Resilient DS Games

- ◆ **Discounted-Sum Games with Rewards**
- ◆ **Satisficing Problem:** Find good-enough strategy for 0 against 1's strategies
 - Reward $>$ threshold
- ◆ **Subject to:** temporally extended goals
 - E.g.: *Every message sent is eventually received.*
- ◆ **Bansal, Chatterjee, V., 2020:** Algorithm for integral discount factors.

COVID-19: What Did Work?

- ◆ The Internet ecosystem is enabling
 - Working from home.
 - Shopping from home.
 - Teaching from home.
 - Learning from home.
- ◆ **Key design principle: Redundancy!**
 - Background: error-correcting codes - 1947, reliable organisms - 1956.
- ◆ **After 2008: bank stress tests**
 - Redundancy of capital

Paul Baran's Vision of a Distributed Network

- ◆ *C.S. Yoo, 2018*: "Baran's motivation for creating his revolutionary approach to communications networking was driven by the dominant issue of the 1960s—the Cold War and *the overhanging threat of nuclear annihilation*. America's nuclear capability depended on maintaining what the strategic defense community called '*minimum essential communication*,' which was the amount of connectivity needed for the U.S. to credibly maintain the threat of *mutually assured destruction*, which most observers believed was essential to deterring the Soviet Union from attempting a preemptive strike.

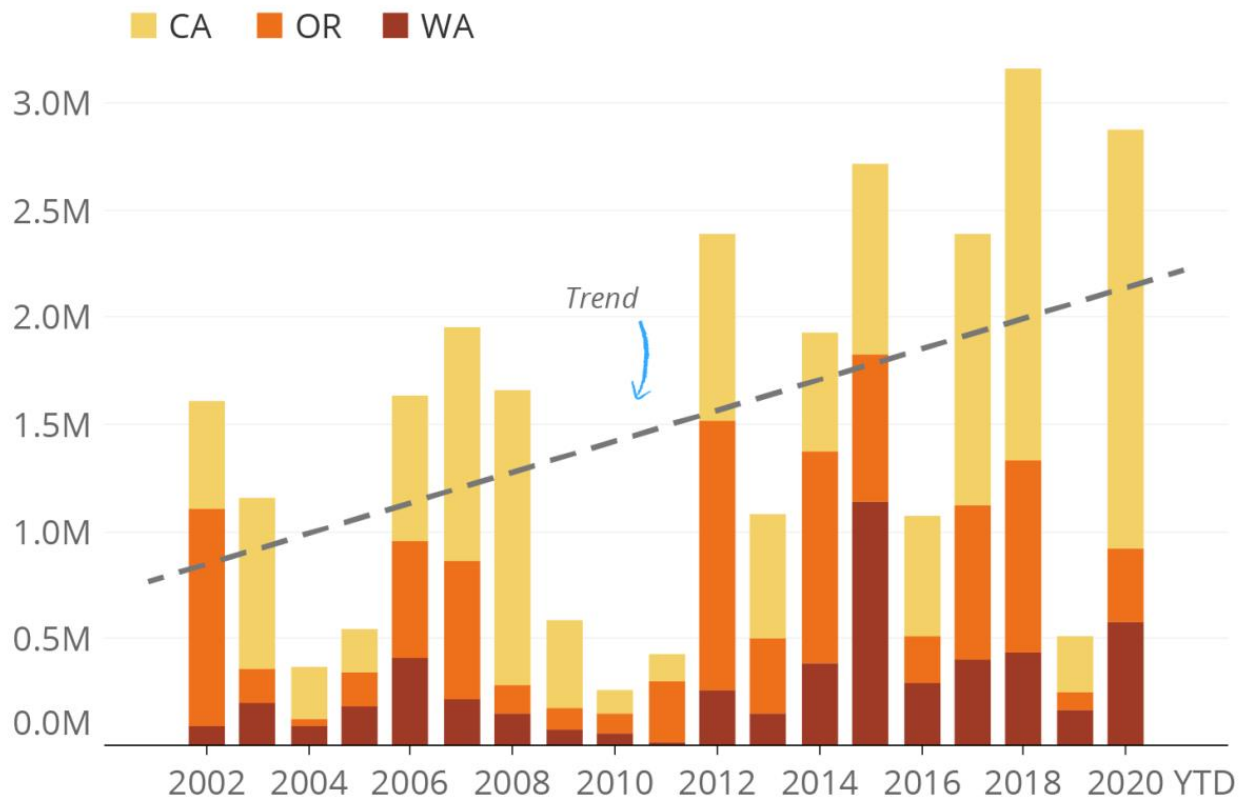
In Summary

- ◆ **Resilience** is a fundamental, but under-appreciated, societal need.
- ◆ Both computing and economics need to increase their focus on resilience.
- ◆ Markets/people are bad at preparing for *low-probability or very long-term events* (e.g., people have to be forced to buy insurance) - ***societal action required***.
- ◆ Covid-19 is just the warm-up act for the ***Climate Disaster***.

How apocalyptic this fire season is

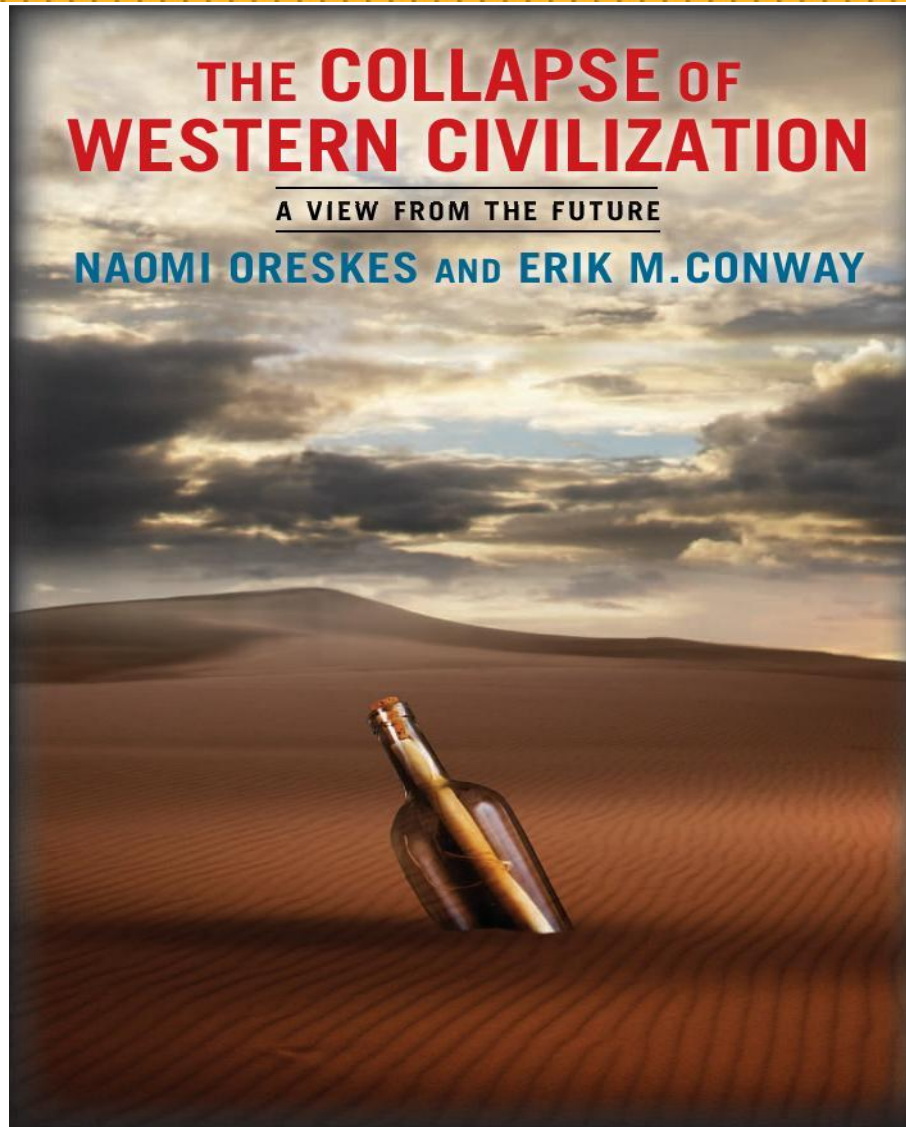
Life on Mars

U.S. Western wildland acres burned, millions



Source: National Interagency Fire Center
2020 data are current through September 9, 2020.

Collapse!



The Risk Society

- ◆ Ulrich Beck, 1986: "The omnipresence of large-scale threats of global scope, anonymous and invisible, are the common denominator of our new epoch."
- ◆ Adam Tooze, FP, 8/20: "The question, so vividly exposed by the crises such as Chernobyl and the ongoing coronavirus pandemic, is how to navigate this world."
- ◆ In summary: *resilience, resilience, resilience!*
- ◆ Fareed Zakaria, WaPo, 10/'20: "The pandemic upended the present. But it's given us a chance to remake the future."