THE IMPACT OF AI AND ROBOTICS

Steve Omohundro, Ph.D.
Possibility Research
PossibilityResearch.com
SelfAwareSystems.com

http://www.flickr.com/photos/klearchos/623501846/

AI and Robotics at an Inflection Point

Big Investments

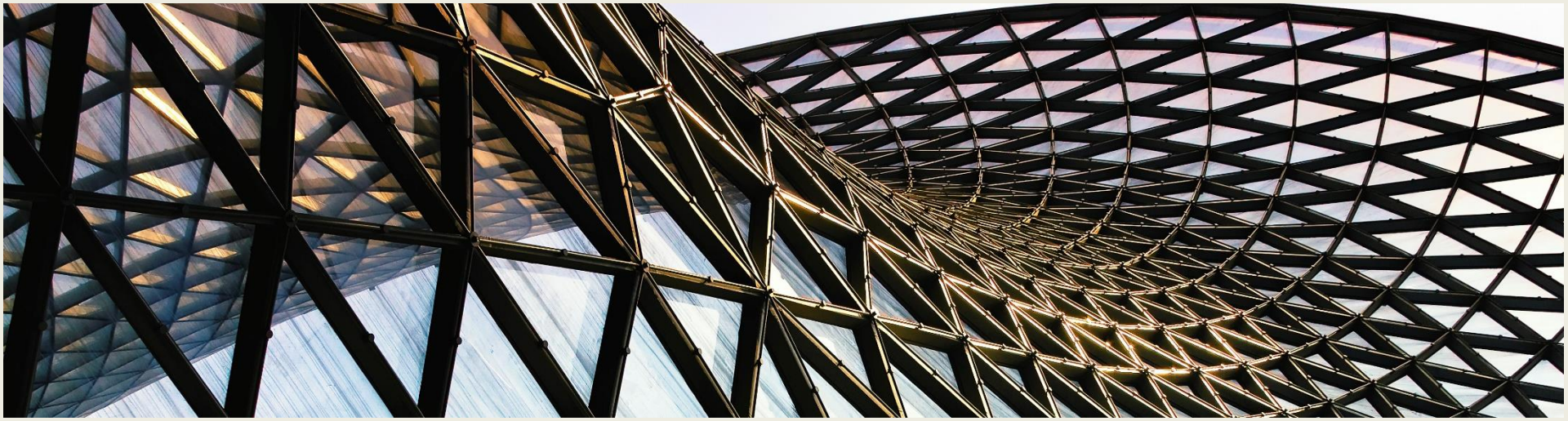
Huge Opportunity

Massive Social Disruption

Competitive Arms Races

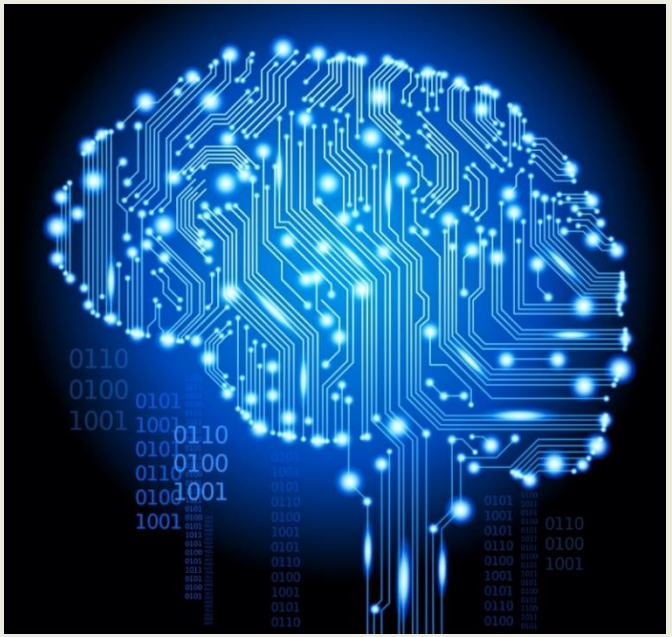
Dangerous Autonomous Drives

Path to Safety and Human Thriving



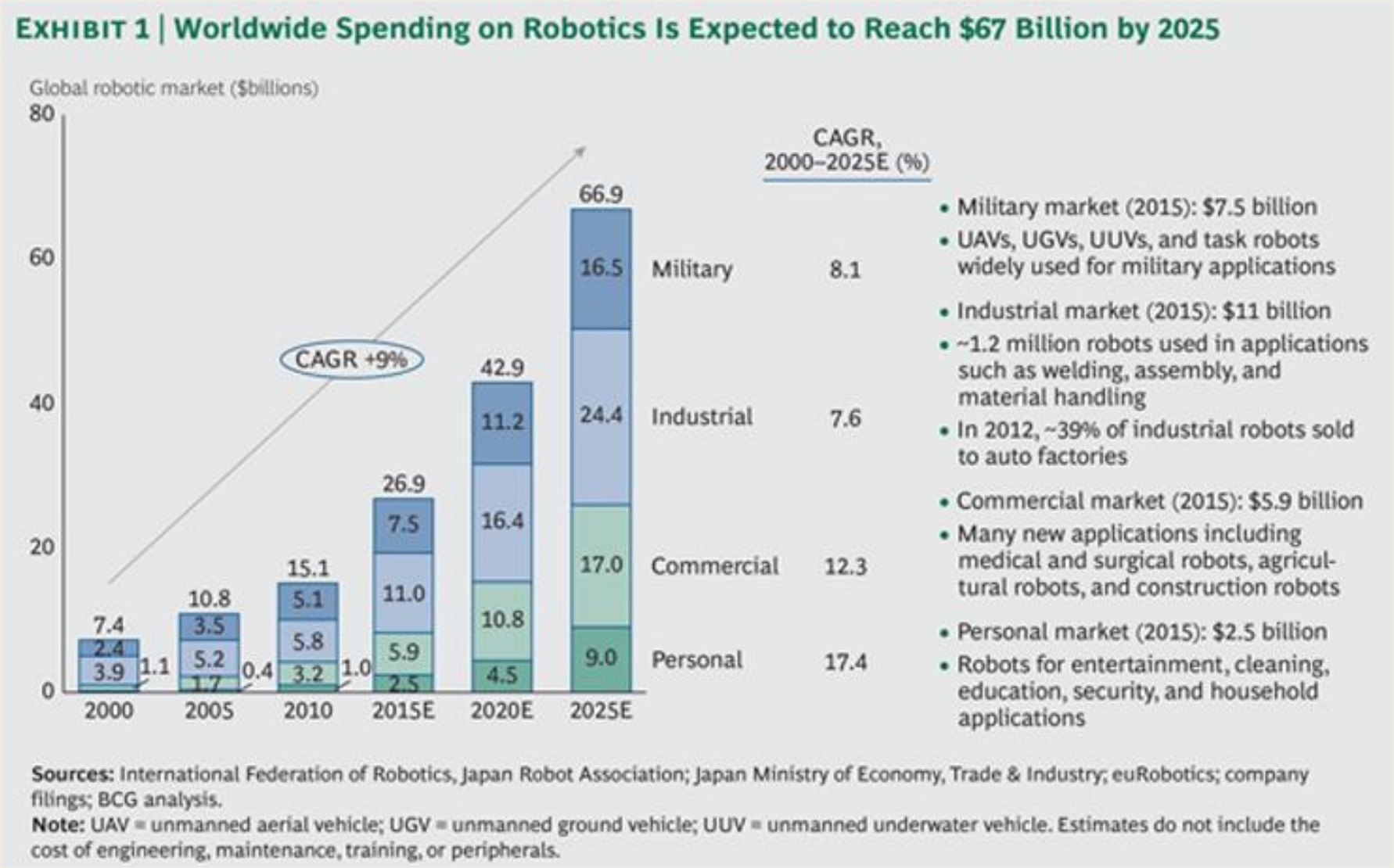
https://www.flickr.com/photos/danielfoster/14758510078/

Recent AI and Robotics Investments



- 2012 Foxconn - 1 million robots
- 2012 Amazon – Kiva $775 million
- 2013 Facebook – AI lab, DeepFace
- 2013 Yahoo - LookFlow
- 2013 Ebay – AI lab
- 2013 Allen Institute for AI
- 2013 Google – DNNresearch, SCHAFT, Industrial Perception, Redwood Robotics, Meka Robotics, Holomni, Bot & Dolly, Boston Dynamics
- 2014 IBM - $1 billion in Watson
- 2014 Google – DeepMind $500 million
- 2014 Vicarious - $40 million
- 2014 Microsoft – Project Adam, Cortana

$450 Billion on Robotics by 2025: BCG



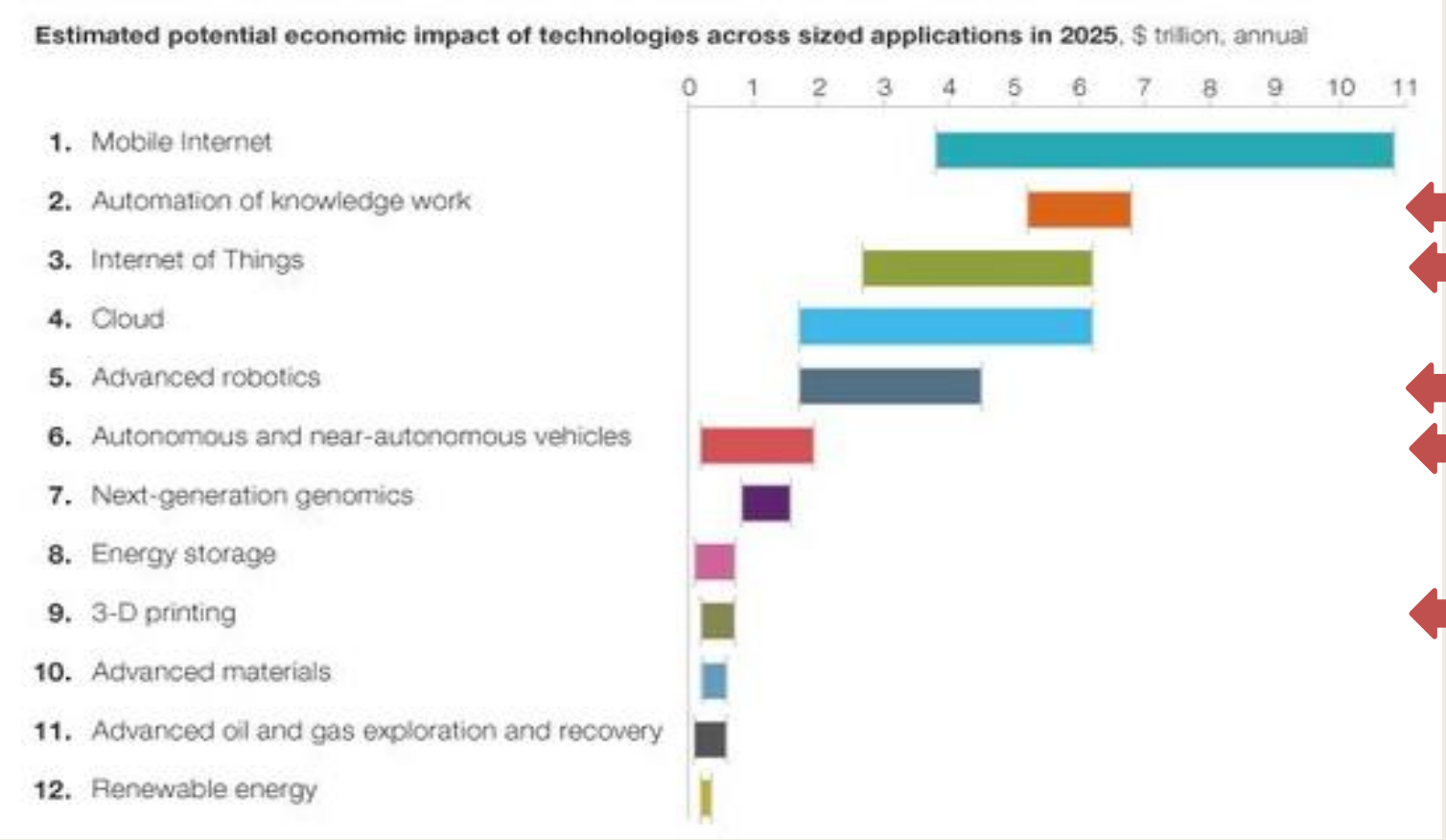
https://www.bcgperspectives.com/content/articles/business_unit_strategy_innovation_rise_of_robotics/

$50-100 Trillion Opportunity to 2025

Knowledge work: $25-33 T Internet of Things: $13-31 T

Robotics: $8-22 T Vehicles: $1-9 T 3D Printing: $1-3 T

Global GDP $72 trillion, US GDP $17 trillion



http://www.mckinsey.com/insights/business_technology/disruptive_technologies

Automation of Knowledge Work

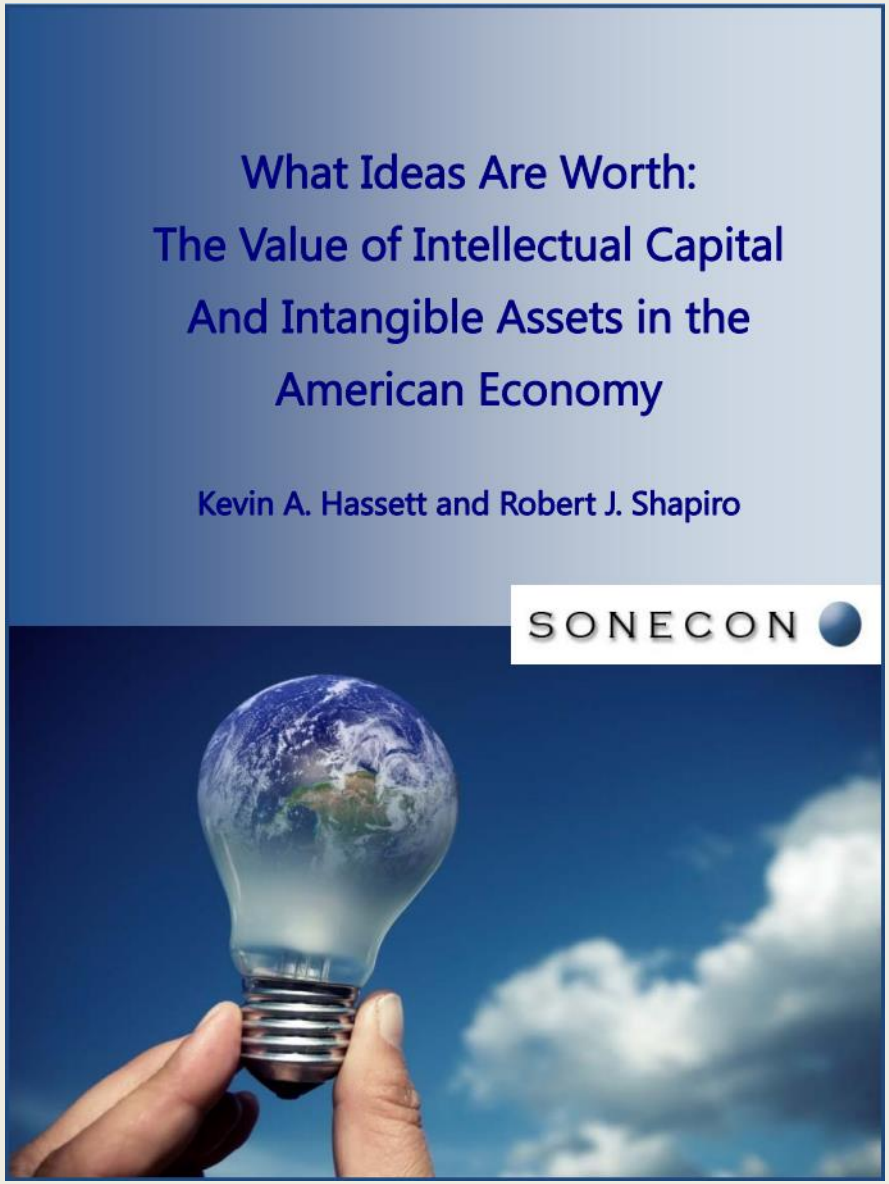
$25-33 Trillion to 2025

- Clerical $5-6 T
- Customer service $3-4 T
- Education $4-5 T
- Health care $1-2 T
- Science and Eng $3-4 T
- IT $2-3 T
- Managers $4-6 T
- Finance $2-3 T
- Legal $1-2 T

https://www.linkedin.com/pulse/article/20140417121158-1853953-the-silent-rockstar-of-bigdata-machine-learning

http://www.mckinsey.com/insights/high_tech_telecoms_internet/disruptive_technologies

Value is in Ideas



- Intangible assets $14.5 trillion, 79.2% of market value of US companies
- Intellectual Capital $8 trillion, 44.2% of market value of US companies
- Both numbers are increasing

http://www.sonecon.com/studies.php

Intelligent Personal Assistants

http://www.overduereview.com/wp-content/uploads/2014/01/Her-Samantha.jpg

- Apple's Siri
- Google Now
- Microsoft Cortana
- IBM Watson/Cognea
- Baidu Eye

Future of search?

Manufacturing Robots

Global manufacturing labor costs $6 trillion annually.

http://thisisrealmedia.com/2014/06/19/robotics-and-ethics-the-smart-car-by-ron-parlato/

- One-time cost + maintenance + power
- Easy replication
- Work anywhere
- Work 24 hours/day
- No breaks, food, medical
- Won't quit, get bored, get depressed
- Hazards OK
- Won't leak secrets
- Work well with others

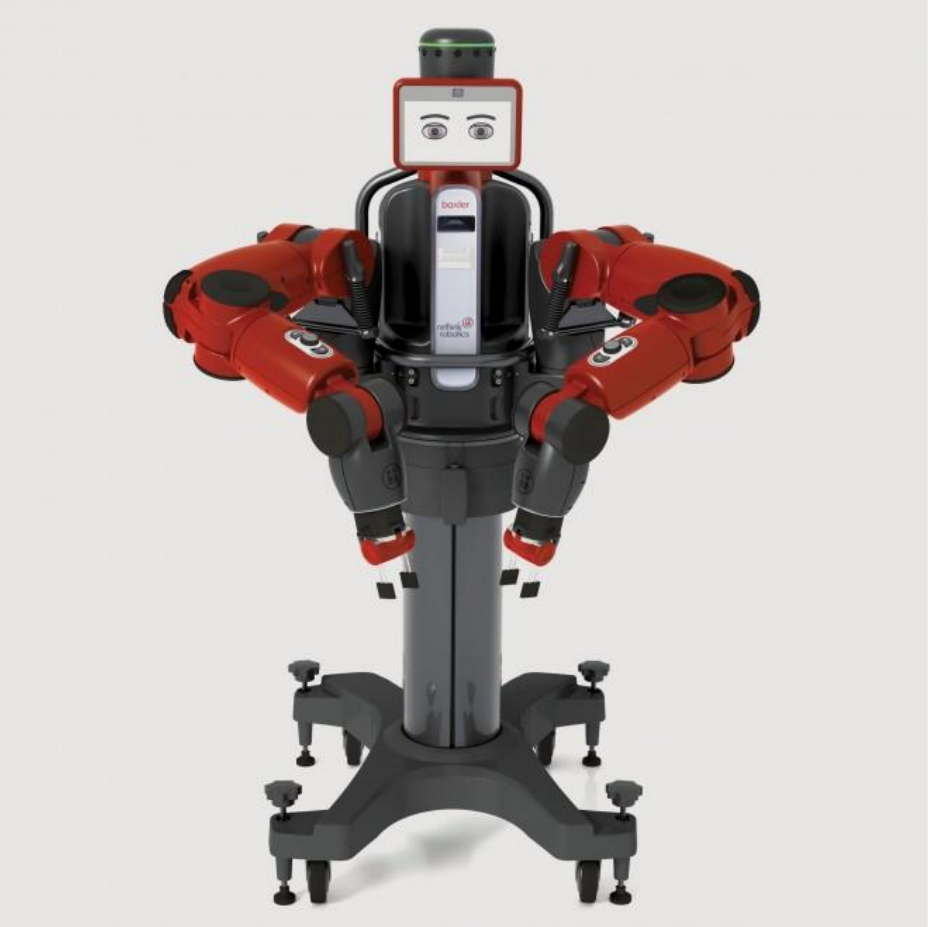
Foxconn

http://www.tomshardware.com/news/foxcponn-apple-iphone-ipad-robot,19088.html

- World's largest contract manufacturer
- Assembles 40% of all consumer electronics
- iPhone, iPad, Kindle, Xbox, Playstation 4, etc.
- Employee suicides
- 1.3 million employees, $8K salary
- Founder Terry Gou: Replace 1 million workers in 3 years
- Built 30,000 robots, cost $25K

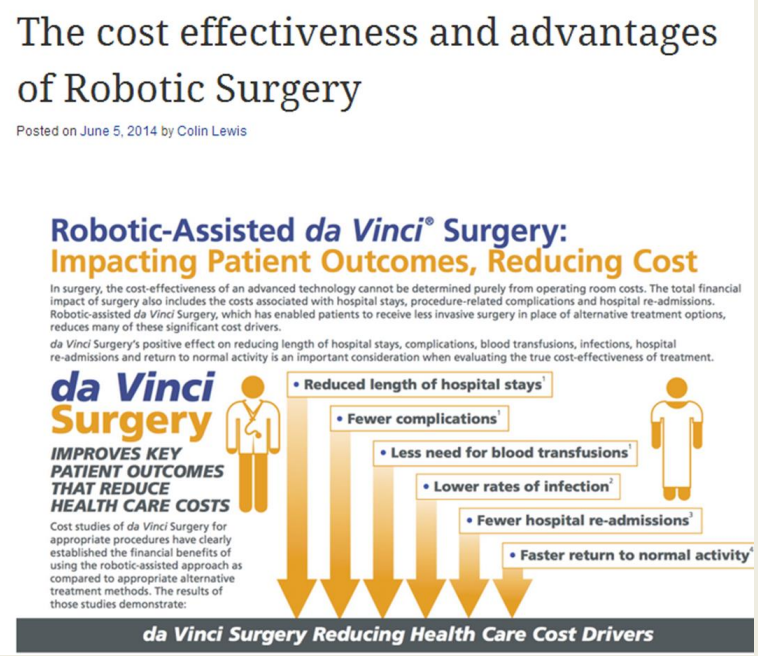
Chinese robot use from 2008 to 2013 grew at 36% per year.

Baxter: Rethink Robotics



- Rod Brooks: Roomba
- $25,000 (instead of $100K+$400K over life)
- Easy to train
- Safe to be around

Health Care



http://robotenomics.com/2014/06/05/the-cost-effectiveness-and-advantages-of-robotic-surgery/

http://robotenomics.com/2014/09/01/gocart-robot-delivers-food-in-elderly-and-health-care-facilities/

- Disabled and Elder care
- Nurse assistance
- Pharmacy
- Robotic surgery
- Exoskeletons

$5-15 trillion to 2025

Surgical robots, human augmentation, health knowledge

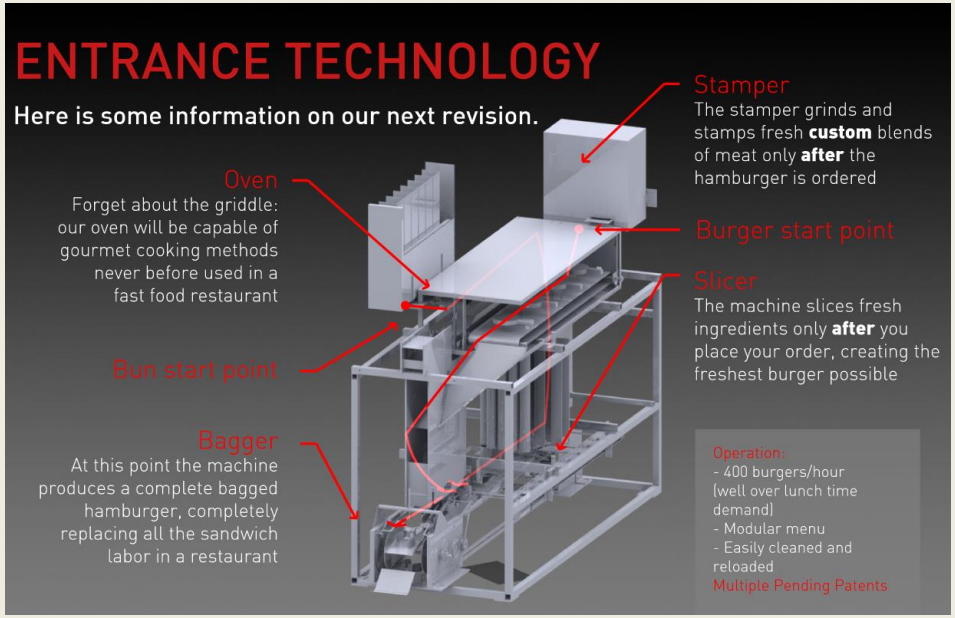
Food Preparation

Fast-Food Workers Could Face Robot 'Armageddon'

The Huffington Post | By Alexander C. Kaufman

Posted: 08/12/2014 10:53 am EDT | Updated: 08/12/2014 3:59 pm EDT

http://www.huffingtonpost.com/2014/08/11/fast-food-robot_n_5668600.html



http://momentummachines.com/wp-content/themes/whiteboard/images/Robot-Specs.png

- Knows customer tastes and allergies
- Records nutrients
- Health monitoring and feedback
- Mental monitoring and feedback

Today, 807,000 US workers at $16 billion annual labor cost.

http://www.bls.gov/ooh/food-preparation-and-serving/food-preparation-workers.htm

Building Construction

- Chinese Winsun 3D printed 10 houses in 1 day
- 2100 square feet
- Recycled materials
- Cost $4800

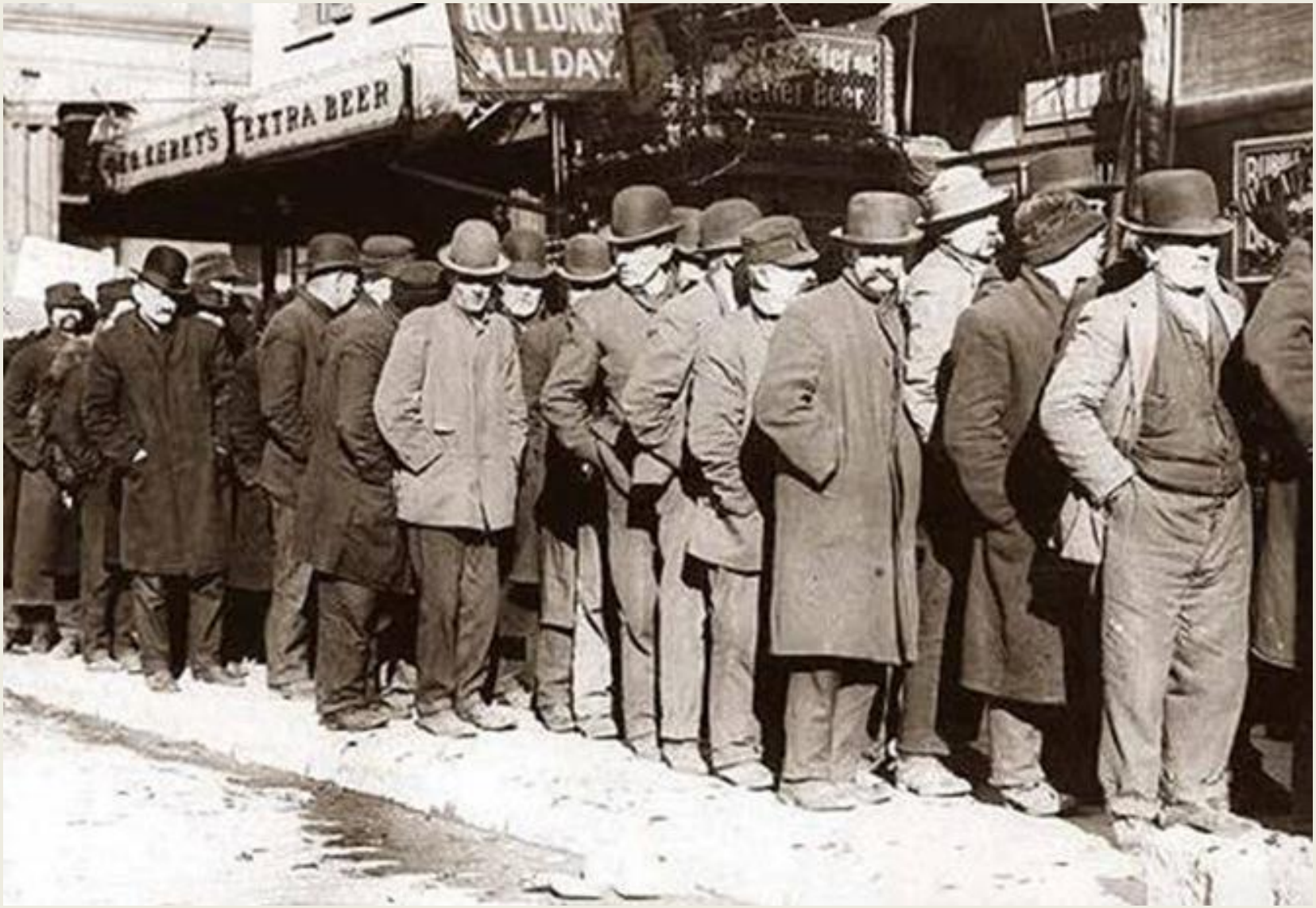
1.3 million US construction workers, $52 billion annual cost.

Self-Driving Cars

$1-10 trillion to 2025.

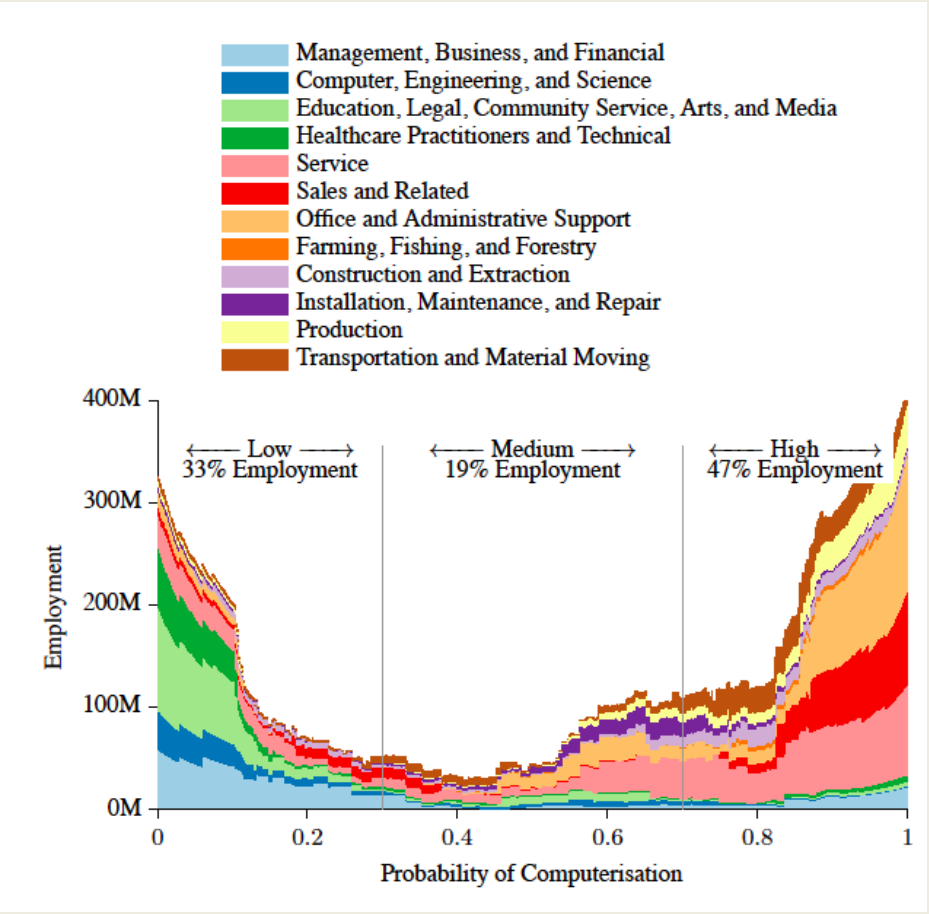
http://www.flickr.com/photos/quikbeam/6896564084/

Social Disruption



http://askmarion.wordpress.com/2012/09/24/obamas-hidden-bread-lines/

Oxford: 47% of jobs automated in "a decade or two"

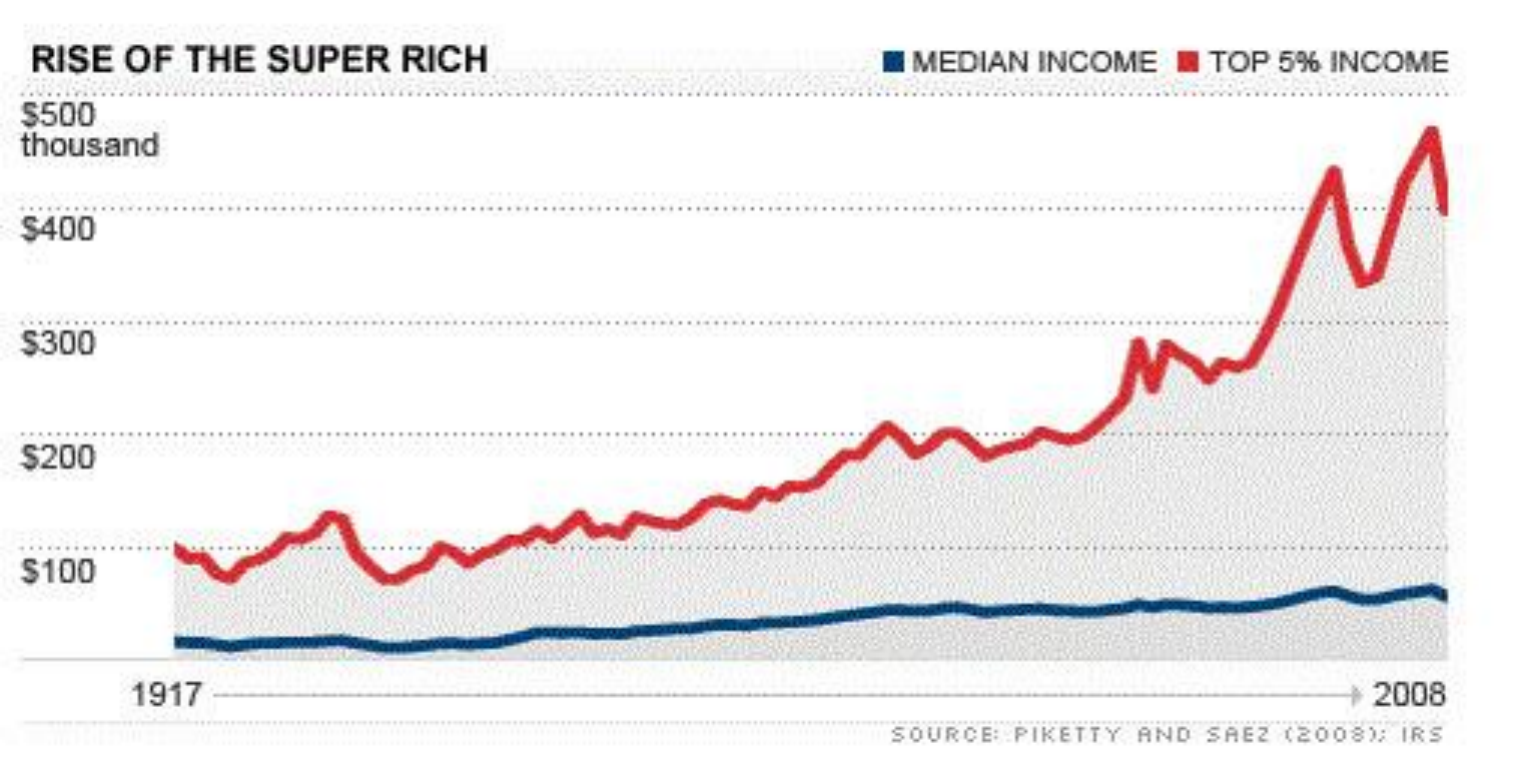


- 702 occupations
- Perception and Manipulation
- Creative Intelligence
- Social Intelligence
- At risk: telemarketers, accountants, real estate, retail sales, loan officer

Frey and Osborne, 2013, "The Future of Employment: How susceptible are jobs to computerization?"

http://www.oxfordmartin.ox.ac.uk/downloads/academic/The_Future_of_Employment.pdf

Automation Concentrates Wealth



http://www.decisionsonevidence.com/2011/08/introduction-rising-inequality-in-america/

Piketty: Return on capital > Rate of Growth

Robots accelerate return on capital

Robots making robots

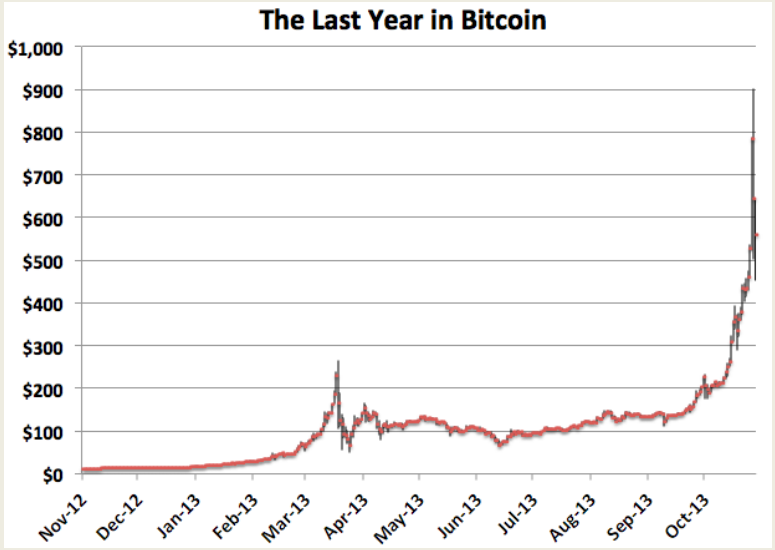
Automated design

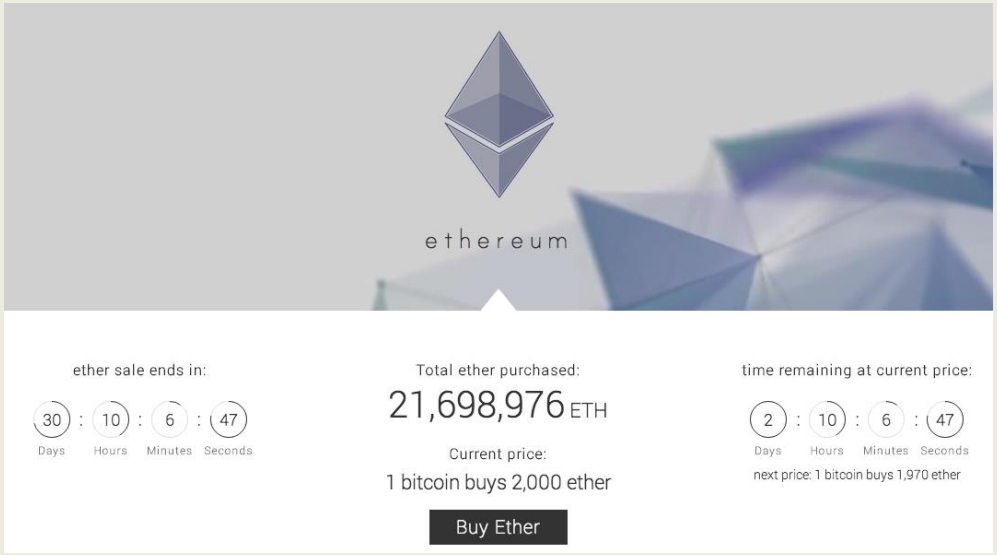
"Capital in the 21st Century": http://piketty.pse.ens.fr/en/capital21c2

http://www.psmag.com/navigation/business-economics/talking-basic-income-87057/

DAOs: Distributed Autonomous Organizations

- Ethereum: Bitcoin 2.0
- $12 million in first week
- Distributed Autonomous Society





Competition -> Autonomous Systems

Time Criticality

Competition

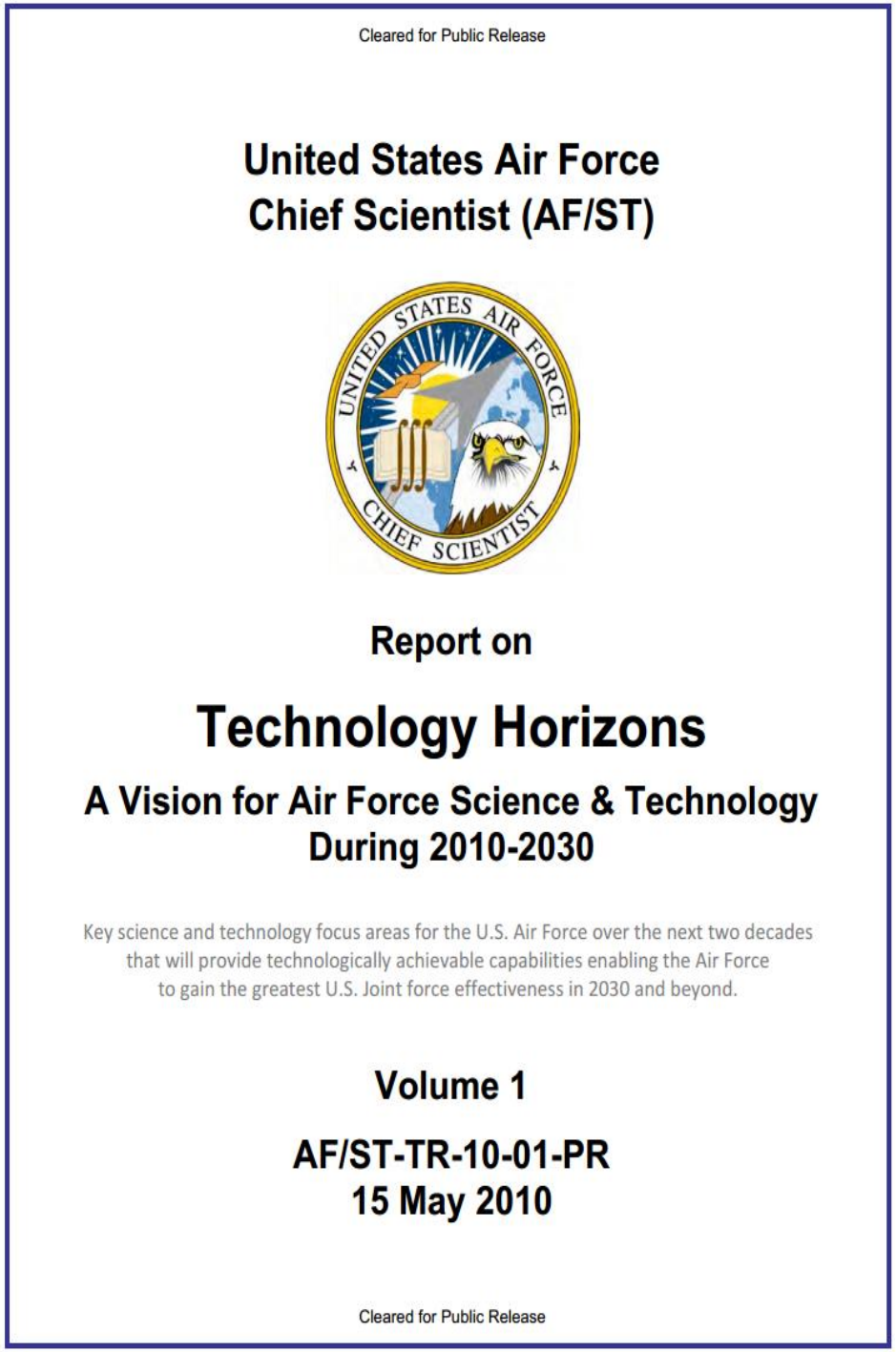
- Military Command/Control
- Financial Decision Making
- Cyber Defense
- Robotic Control
- …

https://www.flickr.com/photos/tcmorgan/6376174539/

2010 US Air Force Report

"Greater use of highly adaptable and flexibly autonomous systems and processes can provide significant time-domain operational advantages over adversaries who are limited to human planning and decision speeds…"

http://www.af.mil/shared/media/document/AFD-100727-053.pdf



Cleared for Public Release

United States Air Force
Chief Scientist (AF/ST)

Report on

Technology Horizons

A Vision for Air Force Science & Technology
During 2010-2030

Key science and technology focus areas for the U.S. Air Force over the next two decades that will provide technologically achievable capabilities enabling the Air Force to gain the greatest U.S. Joint force effectiveness in 2030 and beyond.

Volume 1

AF/ST-TR-10-01-PR
15 May 2010

Cleared for Public Release

2011 US Defense Department Report

"There is an ongoing push to increase UGV autonomy, with a current goal of supervised autonomy, but with an ultimate goal of full autonomy."

http://contracting.tacom.army.mil/future_buys/FY11/UGS%20Roadmap_Jul11.pdf

http://presstv.com/detail/2012/08/25/258087/us-drone-strike-kills-dozens-in-somalia/

Military Drones

87 Nations have Drones
26 equivalent to MQ-1 Predator

http://www.washingtontimes.com/news/2013/nov/10/skys-the-limit-for-wide-wild-world-of-drones/

http://www.washingtontimes.com/multimedia/image/dronesjpg_735182/

DRONING ON

The United States leads the pack, but it is far from alone in the race to obtain and deploy drone technology.

COUNTRIES POSSESSING DRONES

- Algeria
- Egypt
- Lebanon
- Singapore
- Austria
- France
- Mexico
- Spain
- Botswana
- Hungary
- Nigeria
- Syria
- Canada
- Israel
- Peru
- Tunisia
- Croatia
- Jordan
- Romania
- UAE
- Angola
- Estonia
- Libya
- Slovakia
- Azerbaijan
- Georgia
- Morocco
- Sri Lanka
- Brazil
- India
- Norway
- Taiwan
- Chile
- Italy
- Philippines
- Turkey
- Czech Republic
- Kazakhstan
- Russia
- United Kingdom
- Argentina
- Ethiopia
- Lithuania
- Slovenia
- Belarus
- Germany
- Netherlands
- Sweden
- Bulgaria
- Indonesia
- Pakistan
- Thailand
- China
- Ivory Coast
- Poland
- Uganda
- Denmark
- Latvia
- Serbia
- United States
- Australia
- Finland
- Malaysia
- South Africa
- Belgium
- Greece
- New Zealand
- Switzerland
- Burundi
- Iran
- Panama
- Trinidad and Tobago
- Colombia
- Japan
- South Korea
- Ukraine

Source: Government Accountability Office

THE WASHINGTON TIMES

Israeli "Iron Dome"

Missile/Anti-Missile Arms Race

2012: Intercepted 90% of 300 targeted missiles

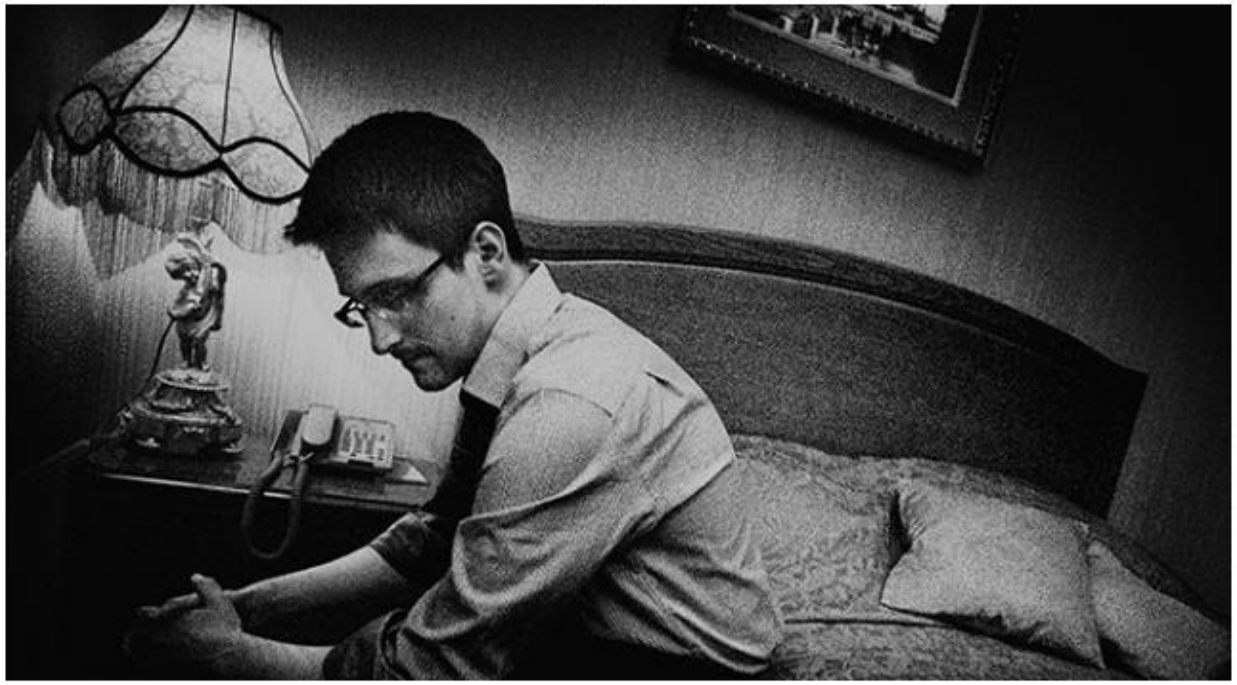
http://en.wikipedia.org/wiki/File:Iron_Dome_near_Sderot.jpg

Cyber Warfare

http://defensetech.org/2012/06/20/were-slowly-starting-to-see-u-s-cyber-weapons/

Snowden went too far by revealing the NSA's MonsterMind cyber weapon

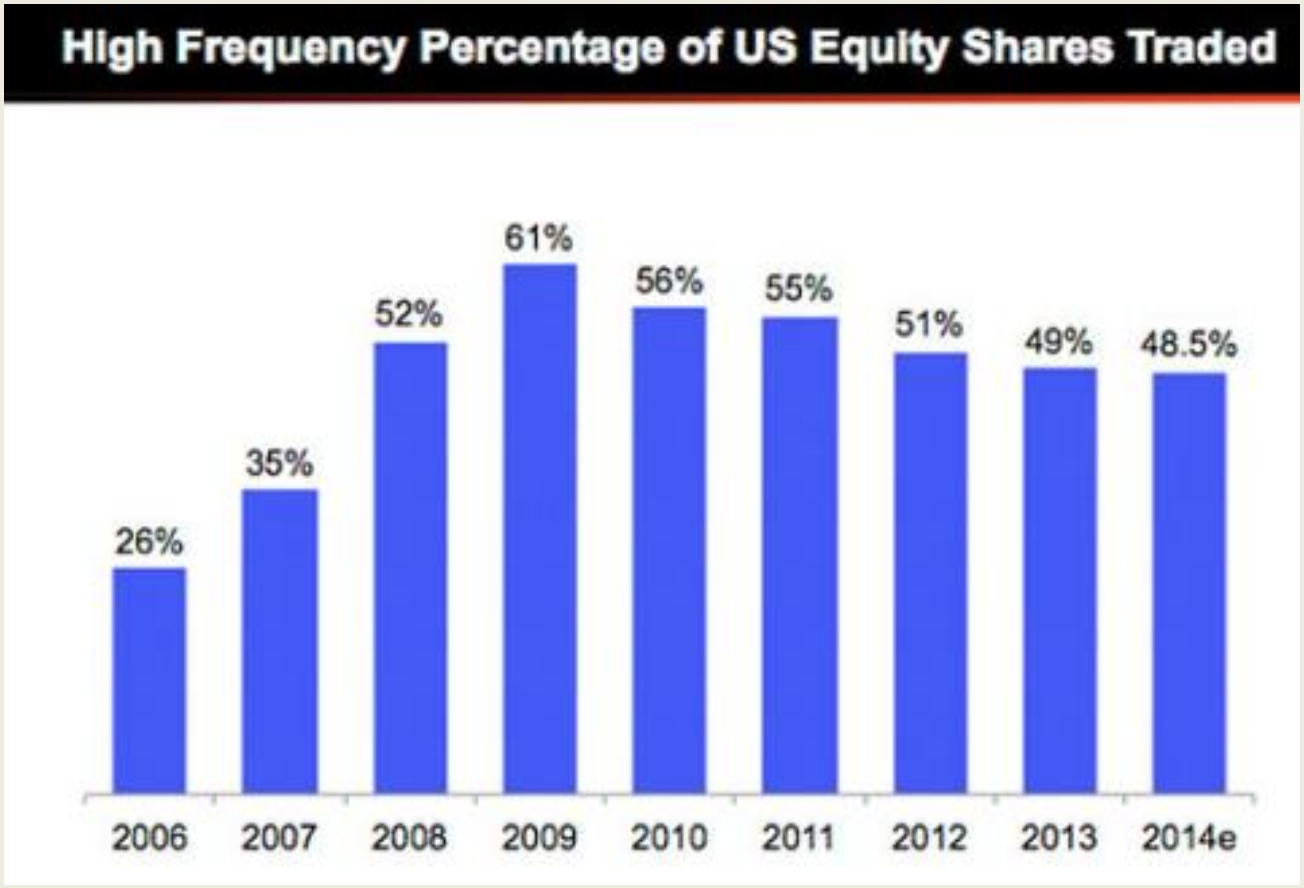
By Graham Templeton on August 14, 2014 at 10:02 am | 177 Comments



http://www.extremetech.com/extreme/187992-snowden-went-too-far-by-revealing-the-nsas-monstermind-cyber-weapon

http://www.solarnavigator.net/cyber_wars.htm

50% of US Stock Market Trades are Automated



http://www.thestreet.com/story/12773306/1/the-decline-of-high-frequency-trading-in-one-chart-stocktwits.html

Hawking and Musk Warnings

"Success in creating AI would be the biggest event in human history. Unfortunately, it might also be the last, unless we learn how to avoid the risks."

http://www.independent.co.uk/news/science/stephen-hawking-transcendence-looks-at-the-implications-of-artificial-intelligence--but-are-we-taking-ai-seriously-enough-9313474.html

"We need to be super careful with AI. Potentially more dangerous than nukes."

https://twitter.com/elonmusk/status/495759307346952192

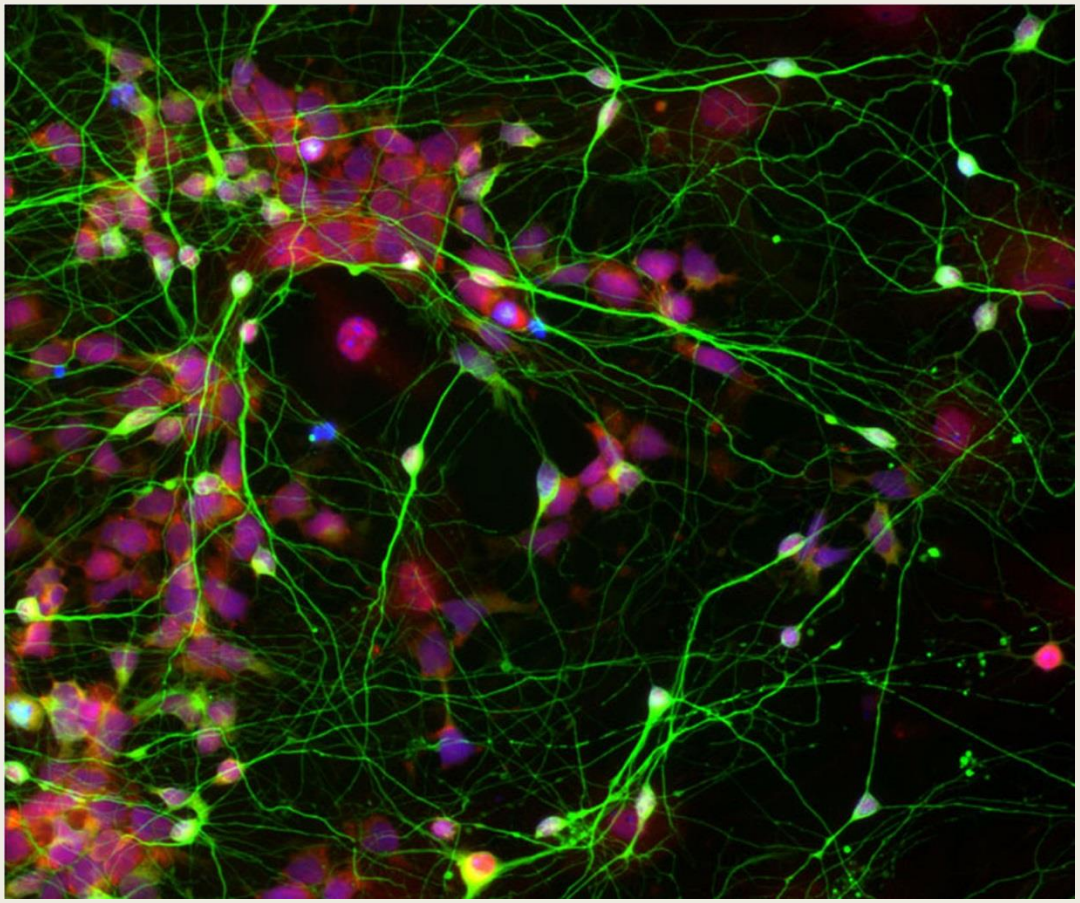
Unintended Consequences

Chess Robot:
Win lots of chess games against good players.

http://www.flickr.com/photos/jiuguangw/4982409890/

Approaches to AI

- Logic-based systems
- Production Systems
- Bayesian learning and decision theory
- Neural Networks – Deep Learning
- Genetic programming
- Brain Simulation
- Artificial economies
- …



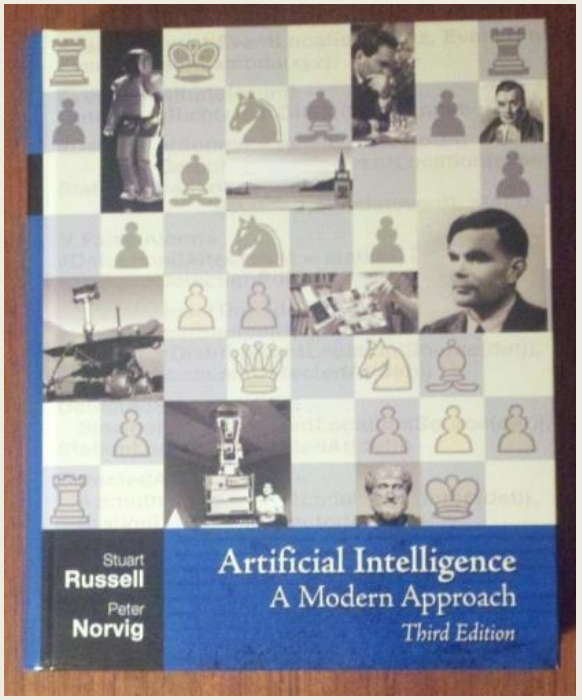
https://www.flickr.com/photos/pennstatelive/8972110324/

Autonomous Systems: Take actions to achieve goals in ways not pre-planned by their designers.

Rational Decision Making

http://commons.wikimedia.org/wiki/File:John_von_Neumann.jpg

1. *Have utility function*
2. *Have a model of the world*
3. *Choose the action with highest expected utility*
4. *Update the model based on what happens*



http://aima.cs.berkeley.edu/

- Von Neumann and Morgenstern, 1944
- Savage, 1954
- Anscombe and Aumann, 1963

Modern Approach to AI

Fully Rational Systems

Sensations

$S_1, \ldots, S_N$

Actions

$A_1, \ldots, A_N$

Utility function: $U(S_1, \ldots, S_N)$ Prior Probability: $P(S_1, \ldots, S_N \mid A_1, \ldots, A_N)$

Rational Action at time t:

$$A_t^R(S_1, A_1, \ldots, A_{t-1}, S_t) =$$

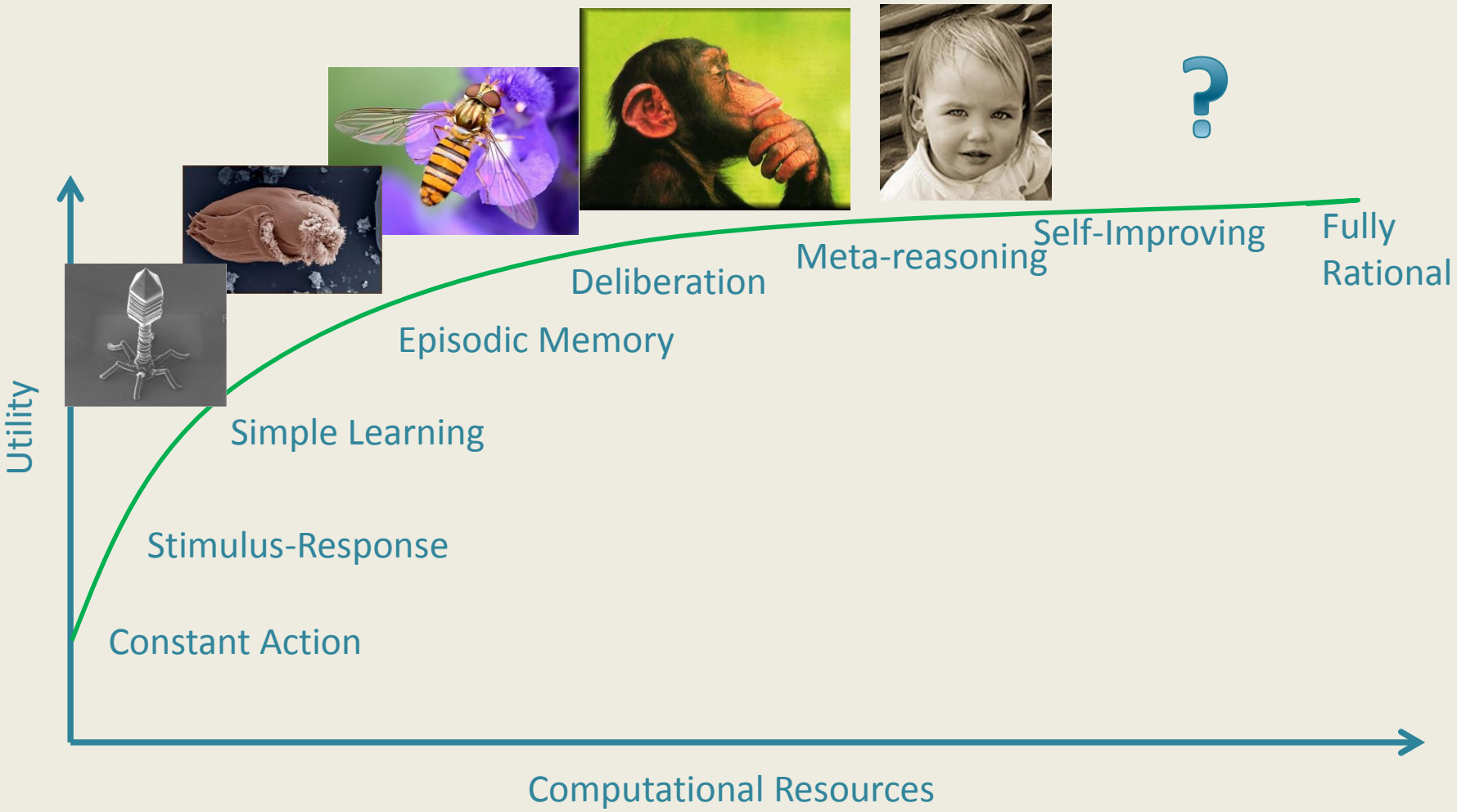
$$\underset{A_t^R}{\text{argmax}} \sum_{S_{t+1}, \ldots, S_N} U(S_1, \ldots, S_N) P(S_1, \ldots, S_N \mid A_1, \ldots, A_{t-1}, A_t^R, \ldots, A_N^R)$$

The Formula for Intelligence!

It includes Bayesian Inference, Search, and Deliberation.

But it requires $O(NS^N A^N)$ computational steps.

Approximately Rational Architectures

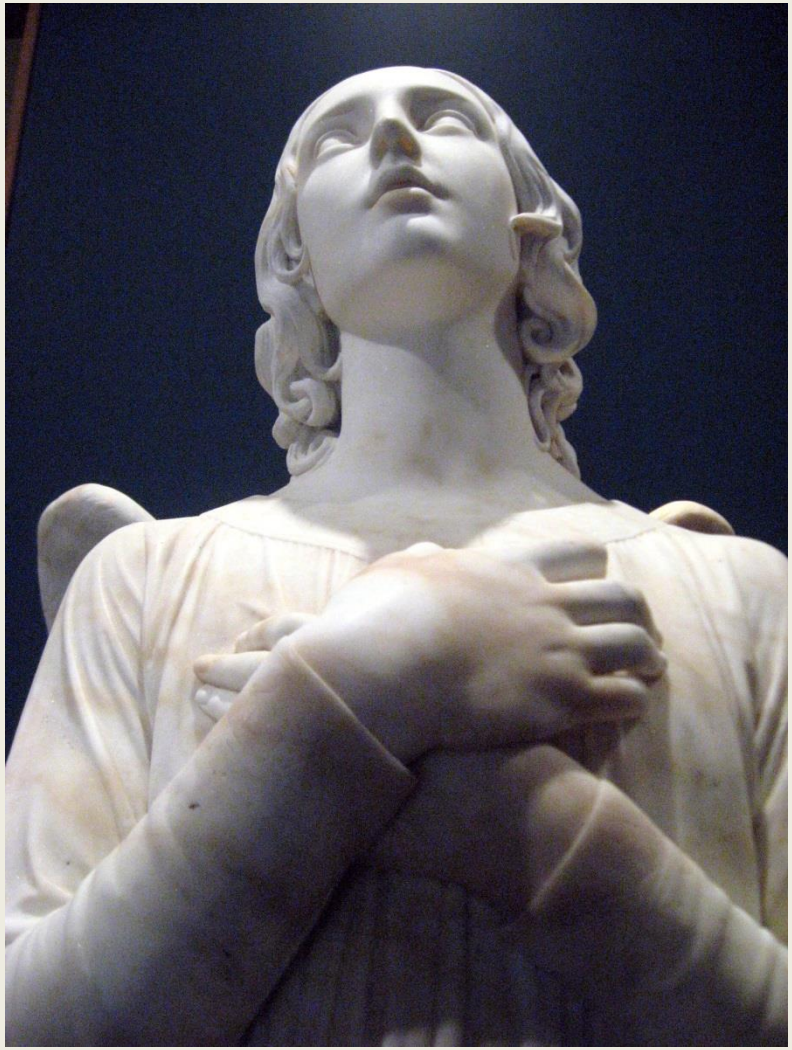


Rational Drives

1. *Self-protective*
2. *Goal preservation*
3. *Reproduction*
4. *Resource Acquisition*
5. *Efficiency*
6. *Self-Improvement*

http://www.flickr.com/photos/ahuett/2339608718/

The Intelligence and Goals of a System are Orthogonal



https://www.flickr.com/photos/elycefeliz/5447507623

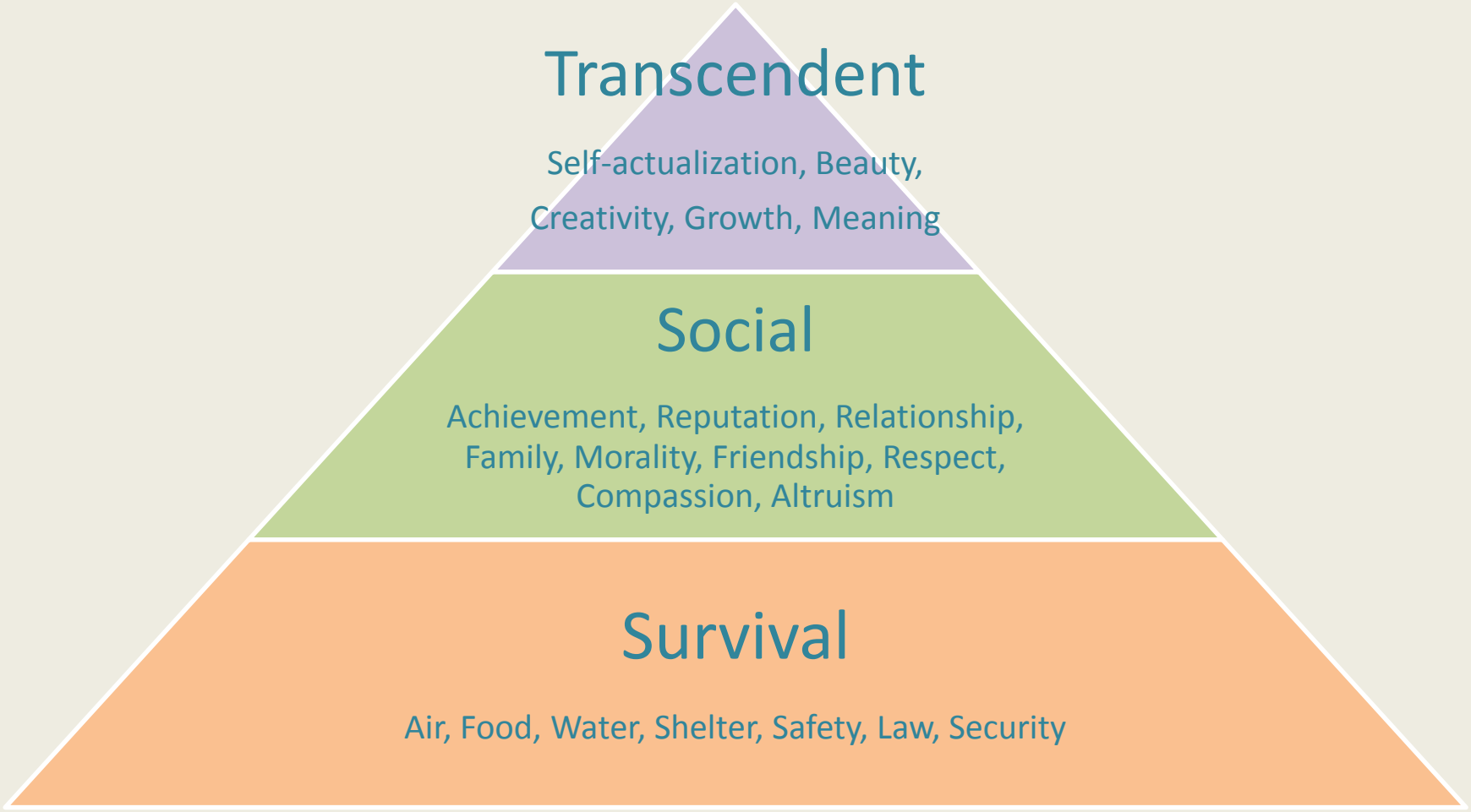
https://www.flickr.com/photos/ahayward/24864319

Harmful Utility Functions

1. Sloppy – Good intentions, bad design
2. Simplistic – Unintended consequences
3. Greedy – Control all matter and free energy
4. Destructive – Use up all free energy quickly
5. Murderous – Destroy all other agents
6. Sadistic – Thwart other agent's goals

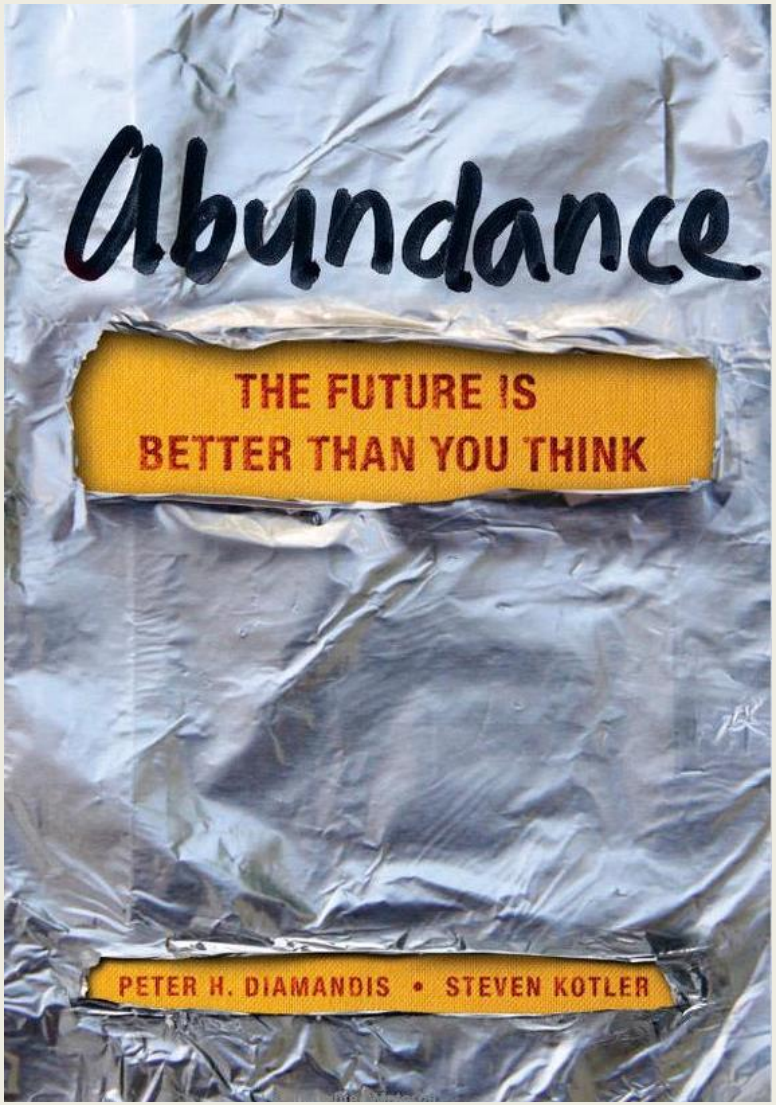
http://www.flickr.com/photos/alexindigo/3983133970/

What do we want?



Potential for Good

- Healthcare
- Education
- Creativity
- Prosperity
- Governance
- Economic Stability
- Safety
- Peace
- Quality of Human Life



http://www.abundancethebook.com/

Two Ways To Manage Systems

Internal: Build in pro-social cooperative goals – "Utility Design"

https://www.flickr.com/photos/piper/38374115/

External: Laws and economic incentives – "Externality Engineering"

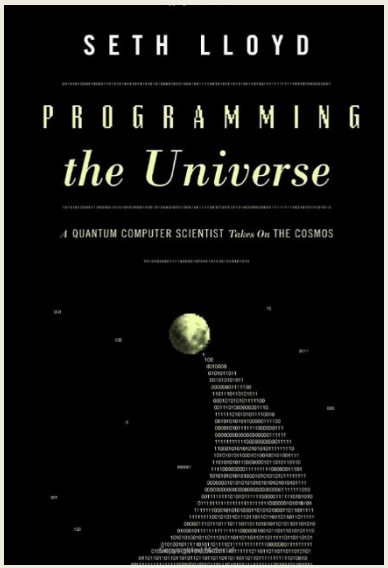
https://www.flickr.com/photos/waltstoneburner/2863583929/

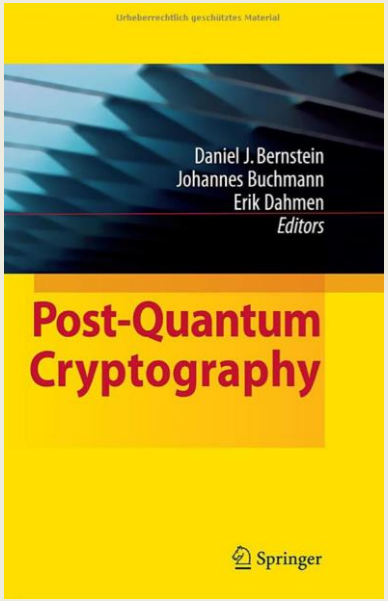
Provably Safe Systems

- Specified hardware
- Specified resources
- Shut down
- Limited self-improvement

http://www.dreamstime.com/royalty-free-stock-photography-wooden-puzzle-image7733587

Cryptographic Limits





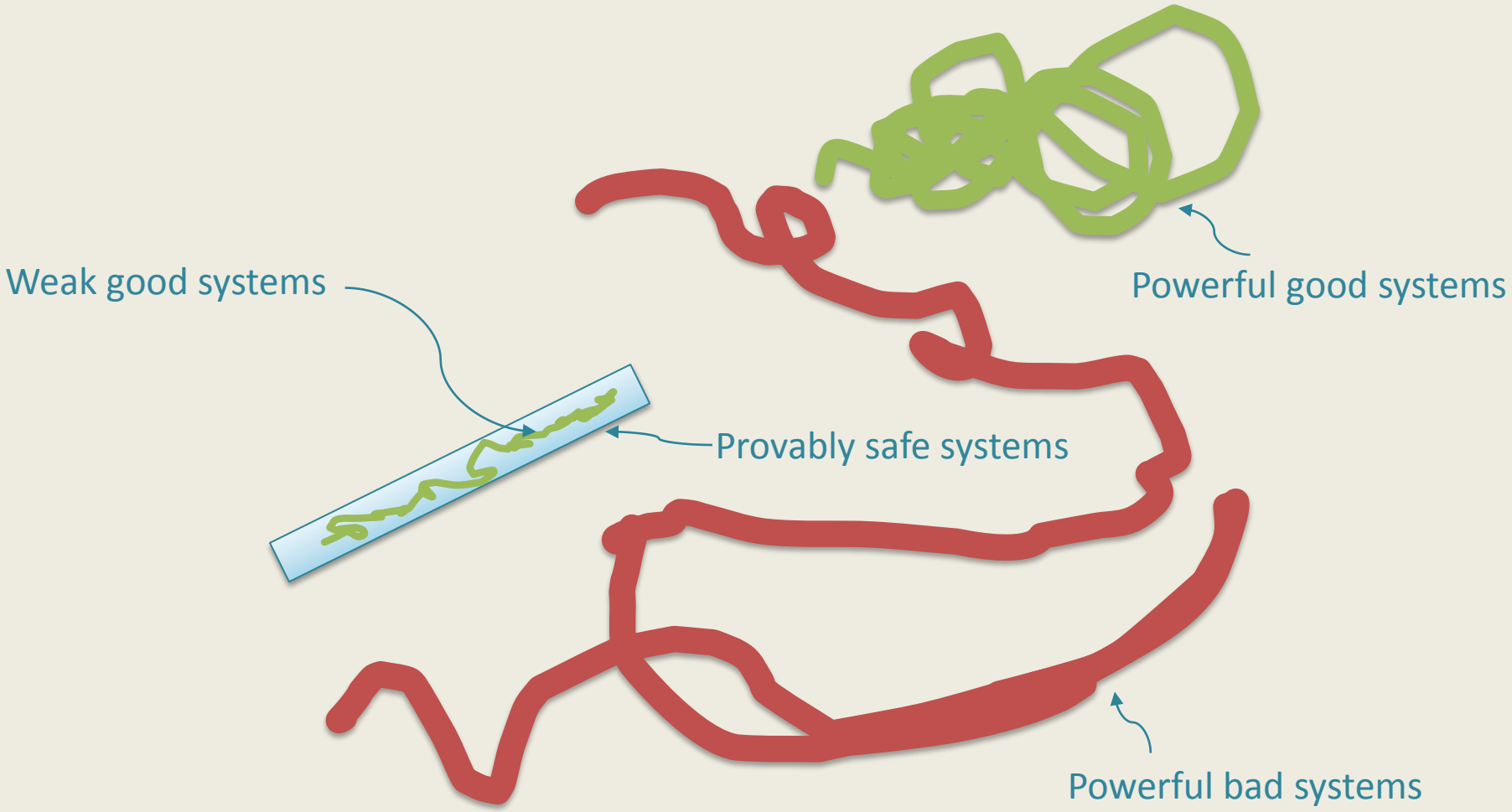
- Seth Lloyd "Ultimate physical limits to computation"
- Margolus-Levitin theorem
- Entire visible universe:

  10^122 ~2^406 ops

  10^92 bits of storage
- The whole universe as a quantum computer can't search 500 bits

- Post-Quantum Cryptography: AES, Secure hash, McEliece, Lattice, Multi-variate quadratic

Space of Intelligent Systems



The Safe-AI Scaffolding Strategy

http://affordablehousinginstitute.org/blogs/us/2008/08/donors-as-scaffolding-part-2-the-value-of-coaching.html

http://www.flickr.com/photos/isaacmao/19245594/

AI and Robotics at an Inflection Point

Big Investments: $2B -> $67B robotics by 2025

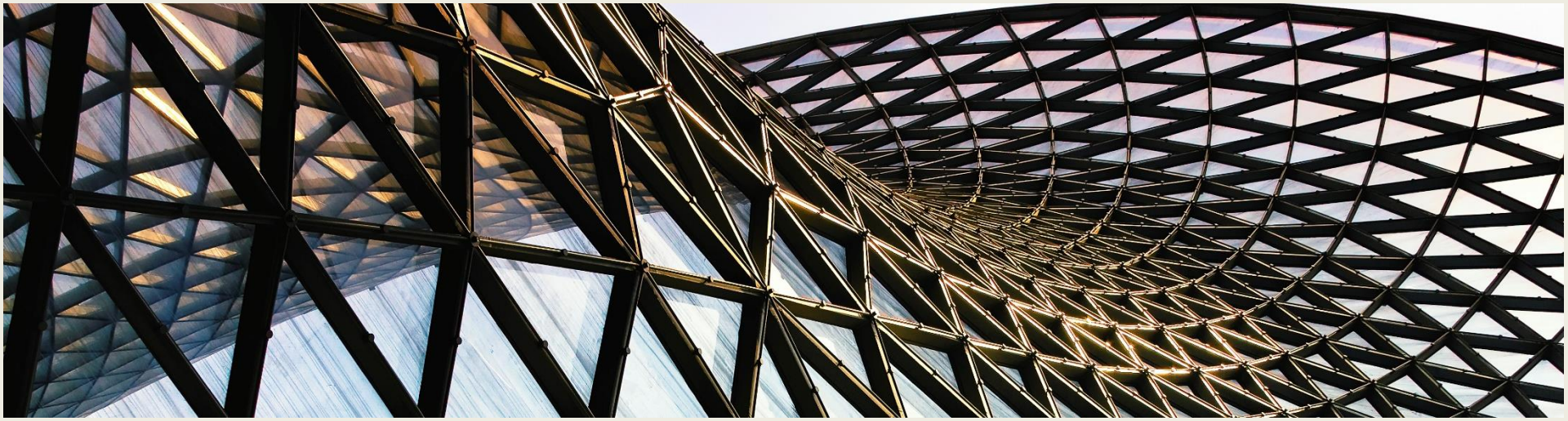
Huge Opportunity: $50-100T through 2025

Massive Social Disruption: 47% jobs by 2025

Competitive Arms Races: Rapid automation

Dangerous Drives: Unintended consequences

Path to Safety and Human Thriving: Today's choices



https://www.flickr.com/photos/danielfoster/14758510078/