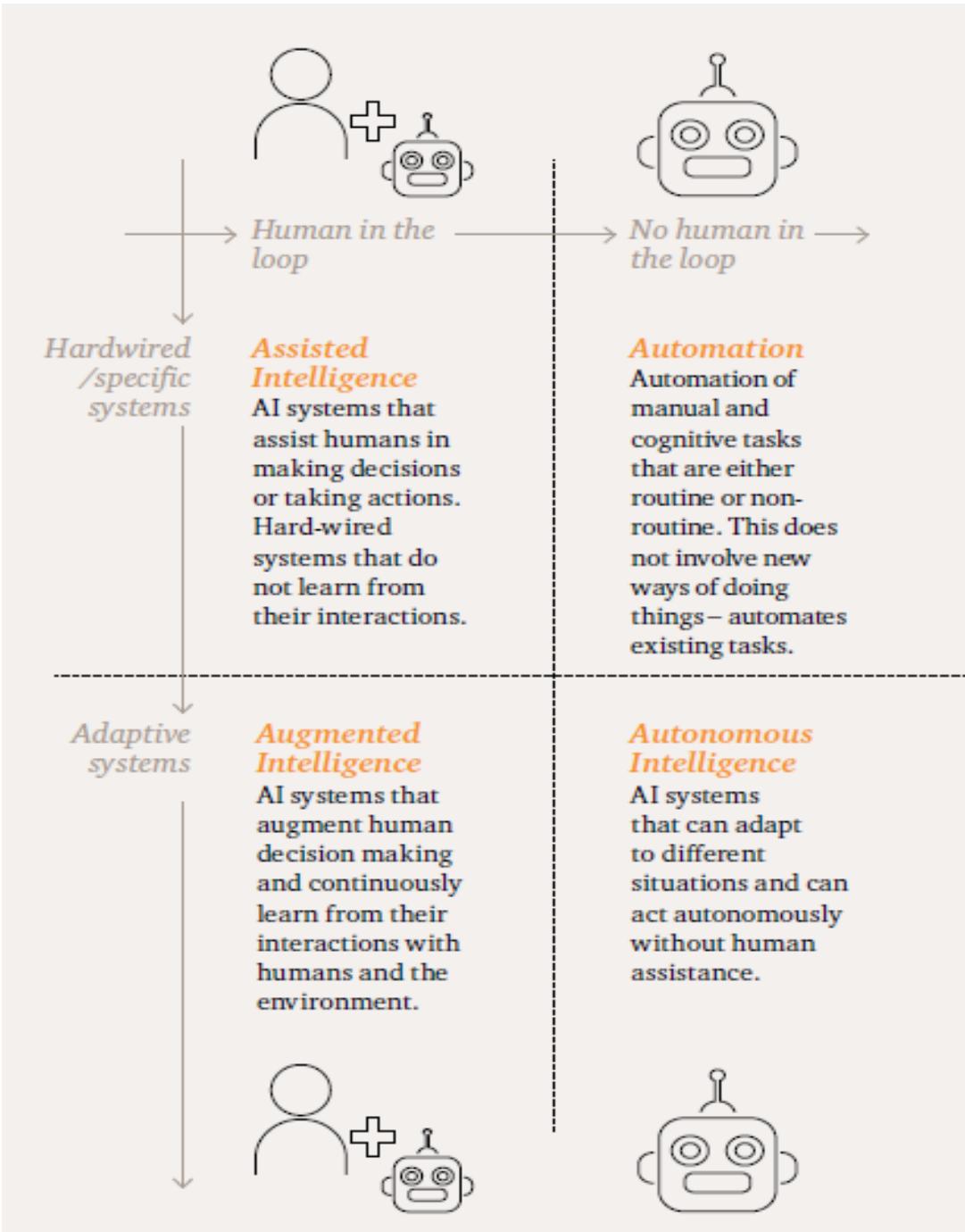


# Artificial Intelligence And Data Science

**Dr. Asim Tewari**

**Professor, Center for Machine Intelligence and Data Science (C-MInDS)  
and Department of Mechanical Engineering,  
IIT Bombay, Powai, Mumbai 400 076, India**





# Are there various kinds of intelligence?

# **What is Artificial Intelligence ?**

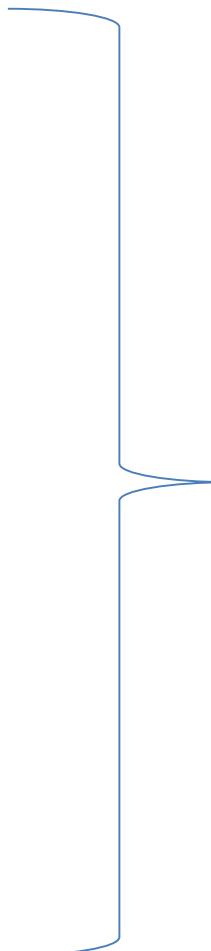
**Artificial Intelligence :** (Merriam-Webster ) The capability of a machine to imitate **intelligent** human behavior.

# **What is Machine Learning ?**

**Machine learning** is a branch of **artificial intelligence** based on the idea that systems can learn from **data**, identify patterns and make decisions with minimal human intervention.

# Data Type

- Discrete data:
  - Discrete non-ordered numbers
  - Random collection of words
  - Unrelated audio sounds
  - Random music notes
- Sequential (temporal) data:
  - Stochastic process
  - Sequence of words in a sentence
  - Audio speech data
  - Music
- Spatial data:
  - Image data
  - Geo-spatial data



**Sequential  
Spatio-temporal  
data**

# Major Components of Data analytics

## 1. Sensor Technology

- Newer modalities
- Higher resolution
- Higher speeds

## 2. Communication and storage

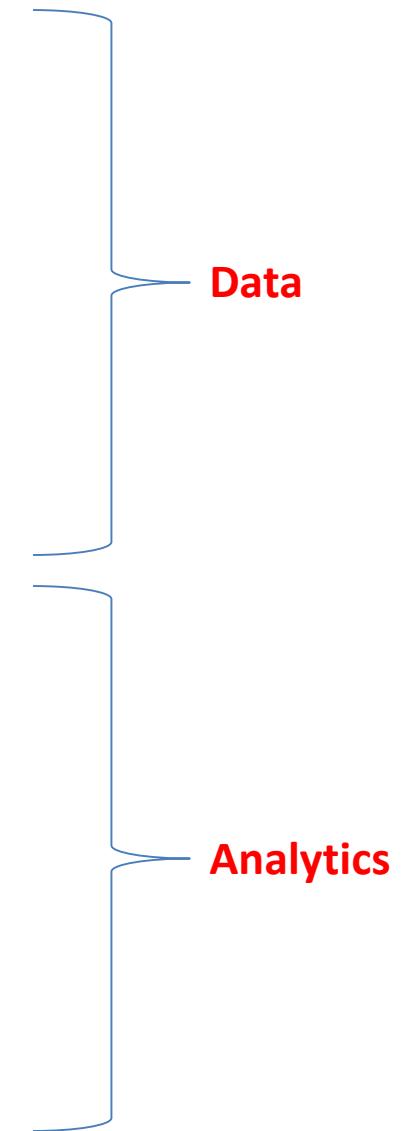
- Challenge of volume, variety and velocity
- Security challenges

## 3. Computational hardware

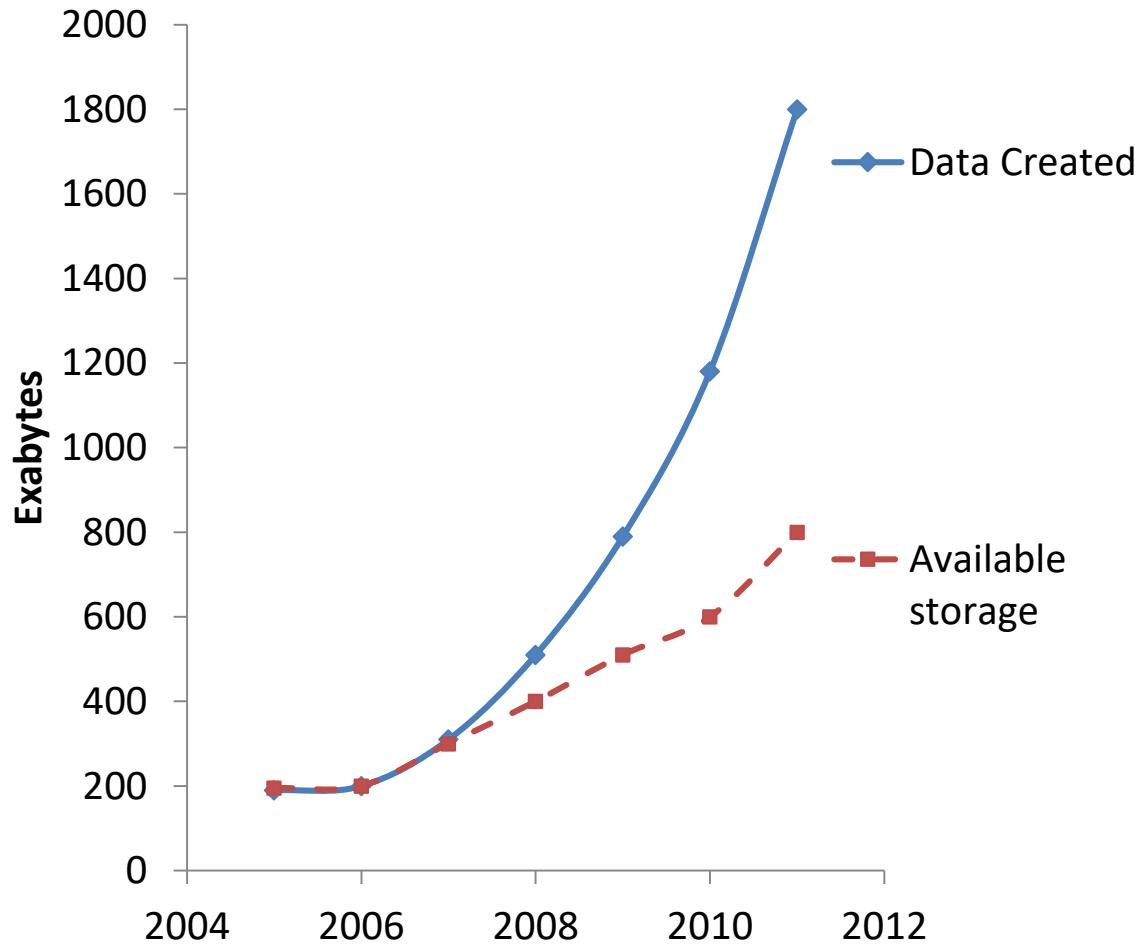
- Cloud computing, GPUs, TPUs, Quantum computing

## 4. Algorithms

- Artificial intelligence (AI)
  - Classical Machine Learning
  - Deep learning
  - Reinforcement Learning



# Information creation is outpacing available storage



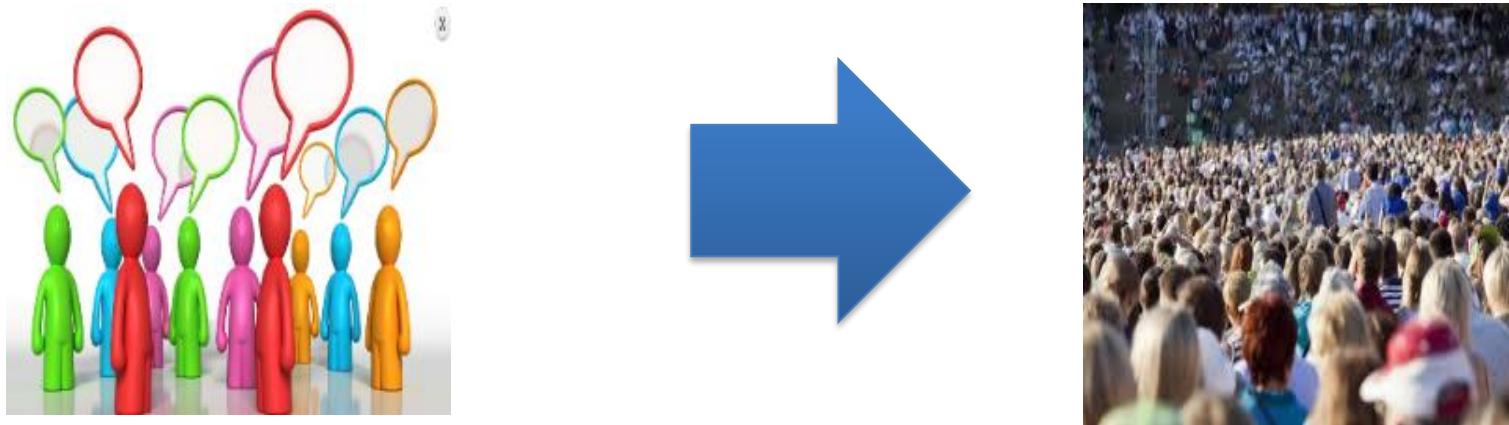
Ref:IDC

# Who's Generating Big Data...

**Old Model:** Few companies are generating data, all others are consuming data



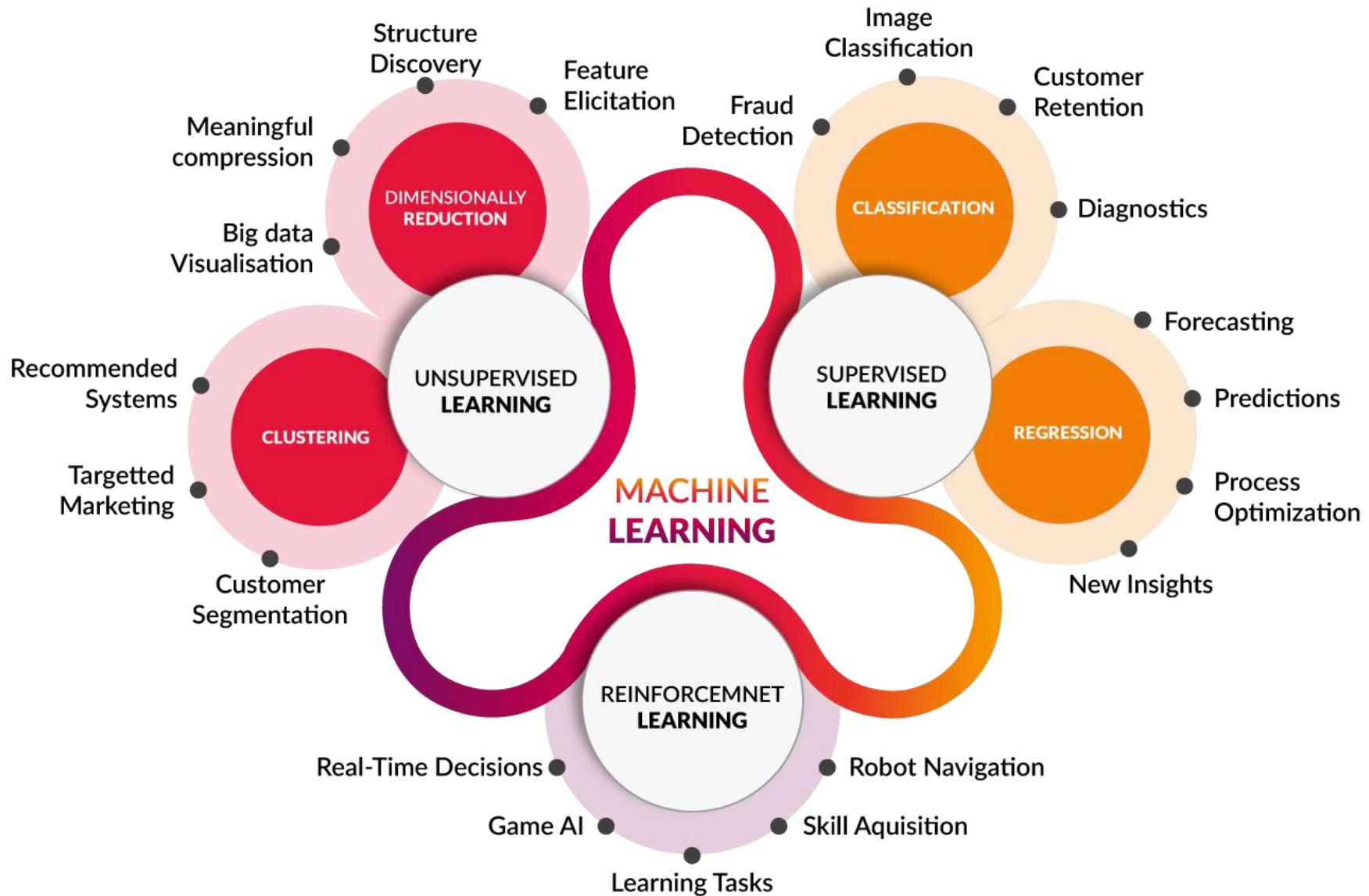
**New Model:** all of us are generating data, and all of us are consuming data



# Major Companies are tracking every move we make

Our cell phones are continuously collecting data:

- Time stamped GPS coordinates and movements (e.g. walking, onBicycle, inRailVehicle, in car, etc)
- The barometric pressure
- The MAC address, signal strength, and frequency of every nearby wifi access point and Bluetooth beacon
- Battery life and charging state of the phone
- Open databases
  - Social Media (FB, Twitter, true-caller,...)
  - Voter ID
  - Auto registration
  - Utility bills
- Amazon Echo and other devices



# Evolution of Artificial Intelligence

- **Artificial Intelligence** : (Merriam-Webster ) The capability of a machine to imitate **intelligent** human behavior.



First Wave

Second Wave

Third Wave

	Activity	Approach	Driver	Capability and performance
AI	Perform a task	Rule based	Definite cost function	Domain specific; lower than human performance

# Machine Learning Techniques in Data analytics

- **Information-based Learning**

- Decision Trees
- Shannon's Entropy
- Information Gain

- **Similarity-based Learning**

- Feature Space
- Distance Metrics

- **Probability-based Learning**

- Naïve Bayes Model
- Markovian model

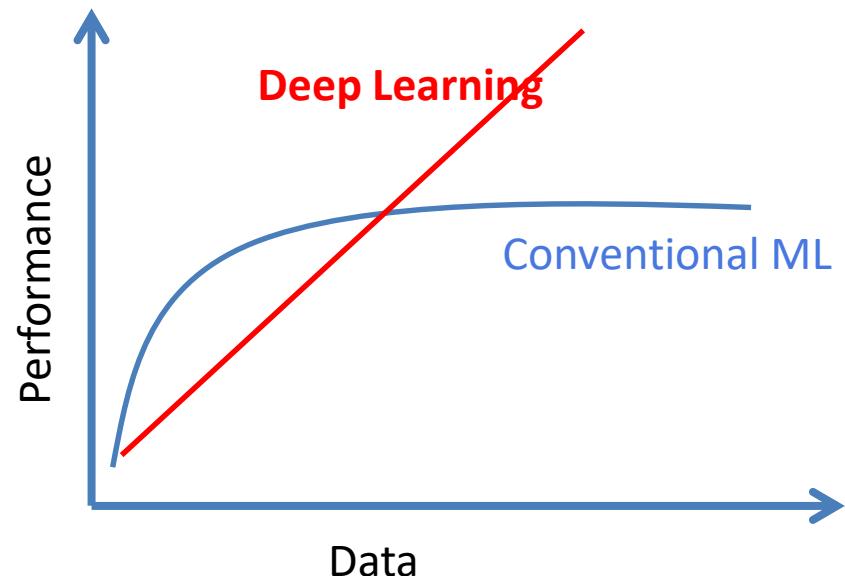
## Deep Learning

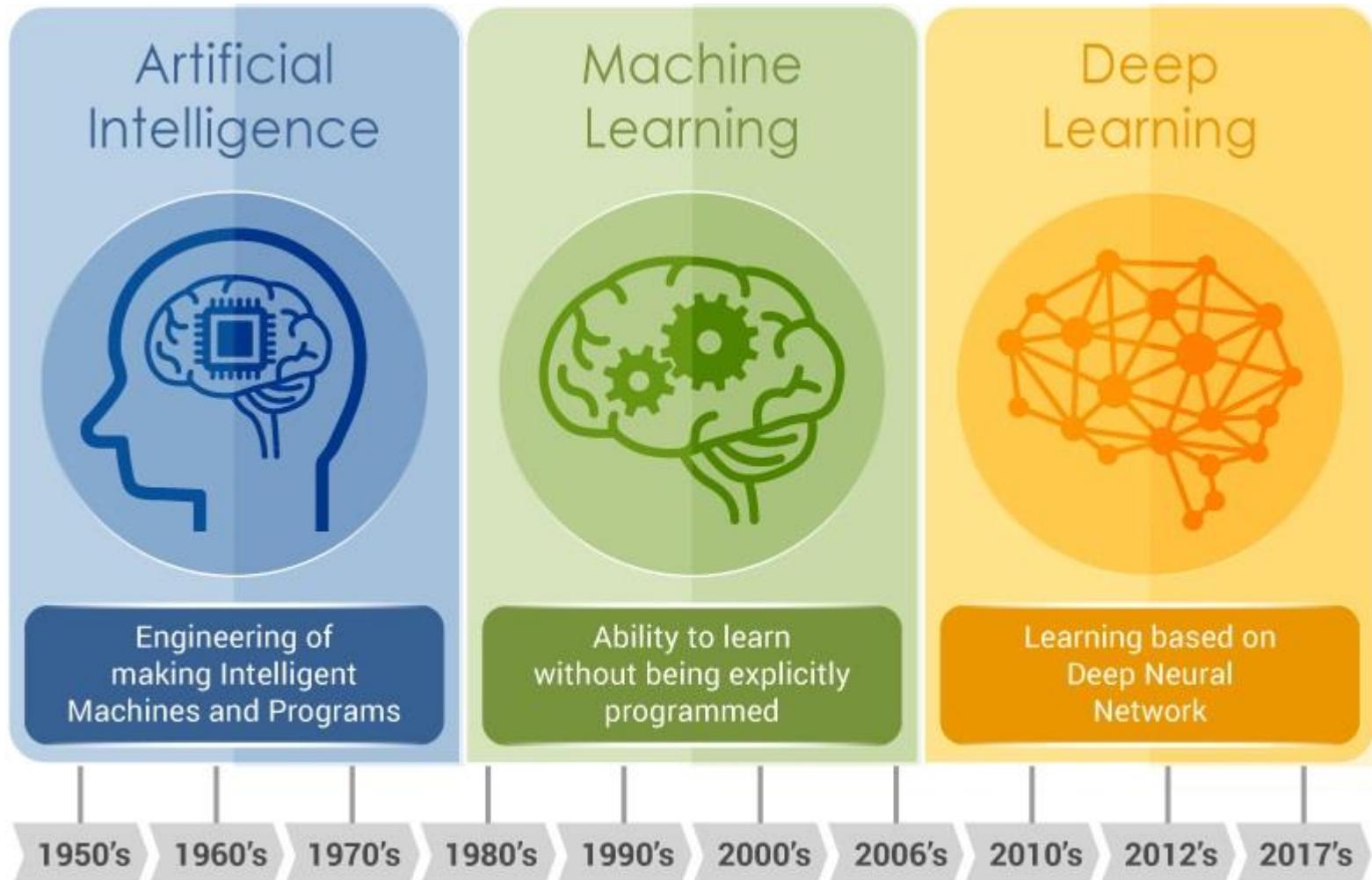
- Convolutional neural network
- Recurrent neural network

- **Error-based Learning**

- Multivariable Regression
- Linear discriminate analysis
- Multinomial Logistic Regression
- Support Vector Machines

- **Expert-system based learning**





# Major Milestones in Machine learning

**1950**

Alan Turing created a test to check if a machine could fool a human being into believing it was talking to a machine.



**1957**

First neural network for computers (the perceptron) was invented by Frank Rosenblatt, which simulated the thought processes of the human brain.



**1979**

Students of Stanford University, California, invented the Stanford Cart which could navigate and avoid obstacles on its own.



**2002**

A software library for Machine Learning, named Torch is first released.



**1952**

The first computer learning program, a game of checkers, was written by Arthur Samuel.



Conventional ML

**1967**

The Nearest Neighbor Algorithm was written.

**1997**

IBM's Deep Blue beats the world champion at Chess.

**2016**

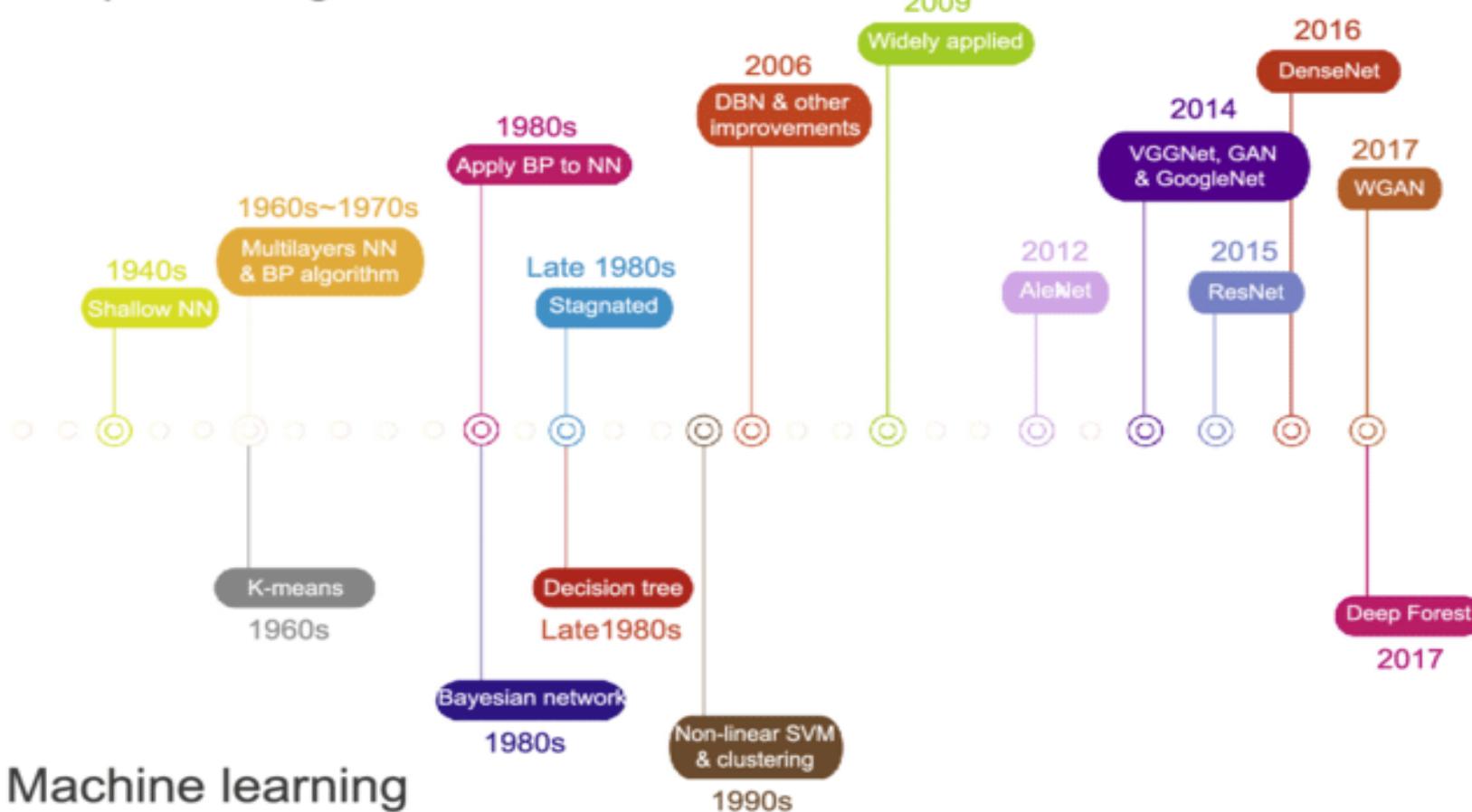
AlphaGo algorithm developed by Google DeepMind managed to win five games out of five in the Chinese Board Game Go competition.



Deep Learning

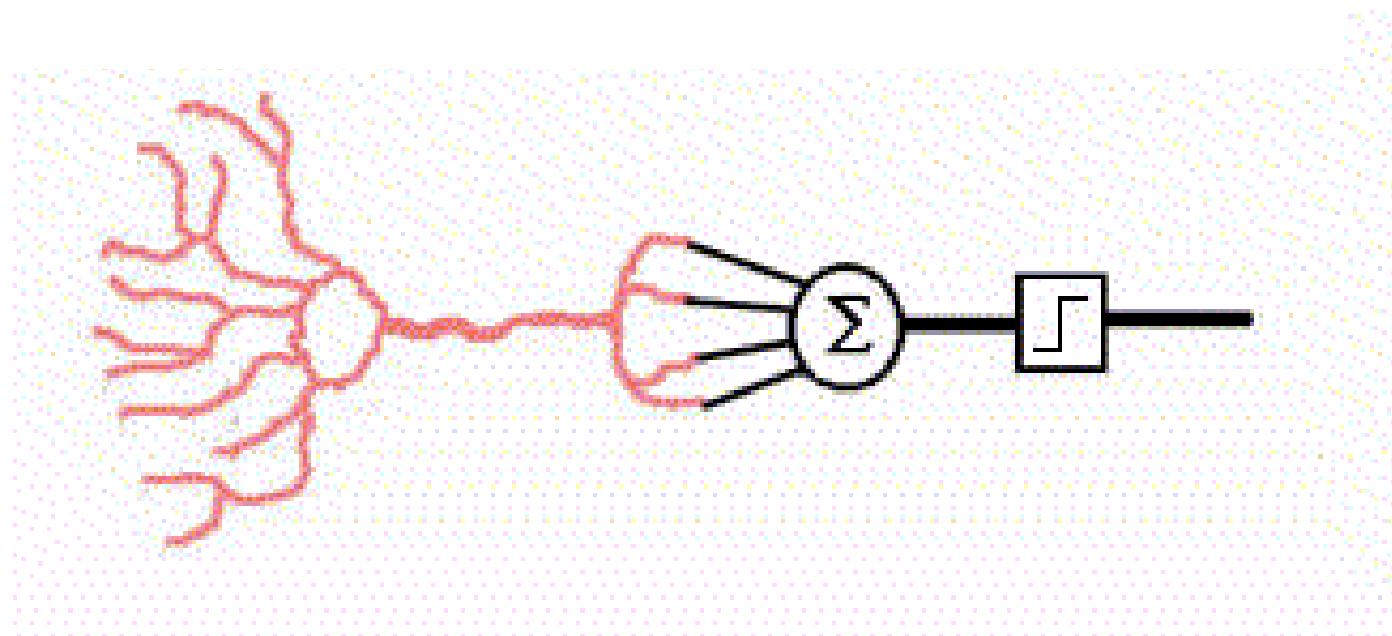
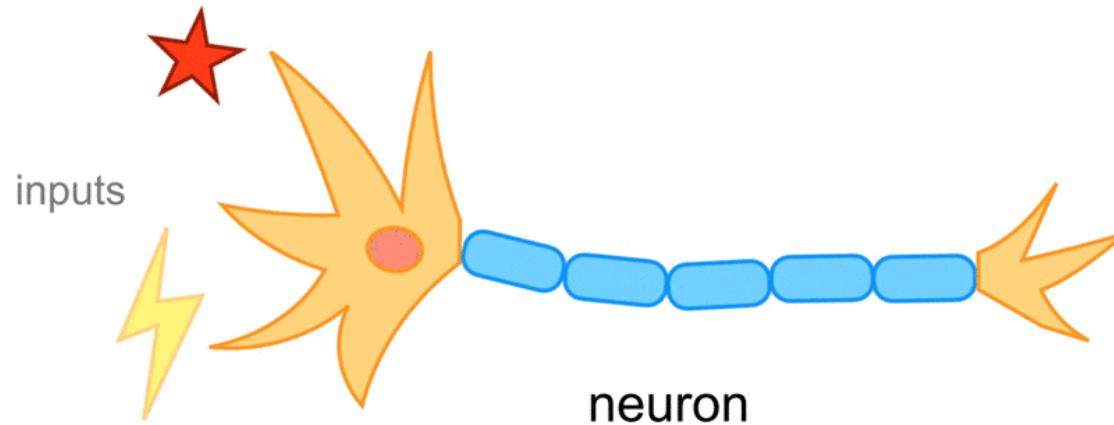
# Classical ML and DL

## Deep learning



## Machine learning

# Neuron is a binary switch (Logistic Regression)



# Evolution of Artificial Intelligence

- **Artificial Intelligence** : (Merriam-Webster ) The capability of a machine to imitate **intelligent** human behavior.



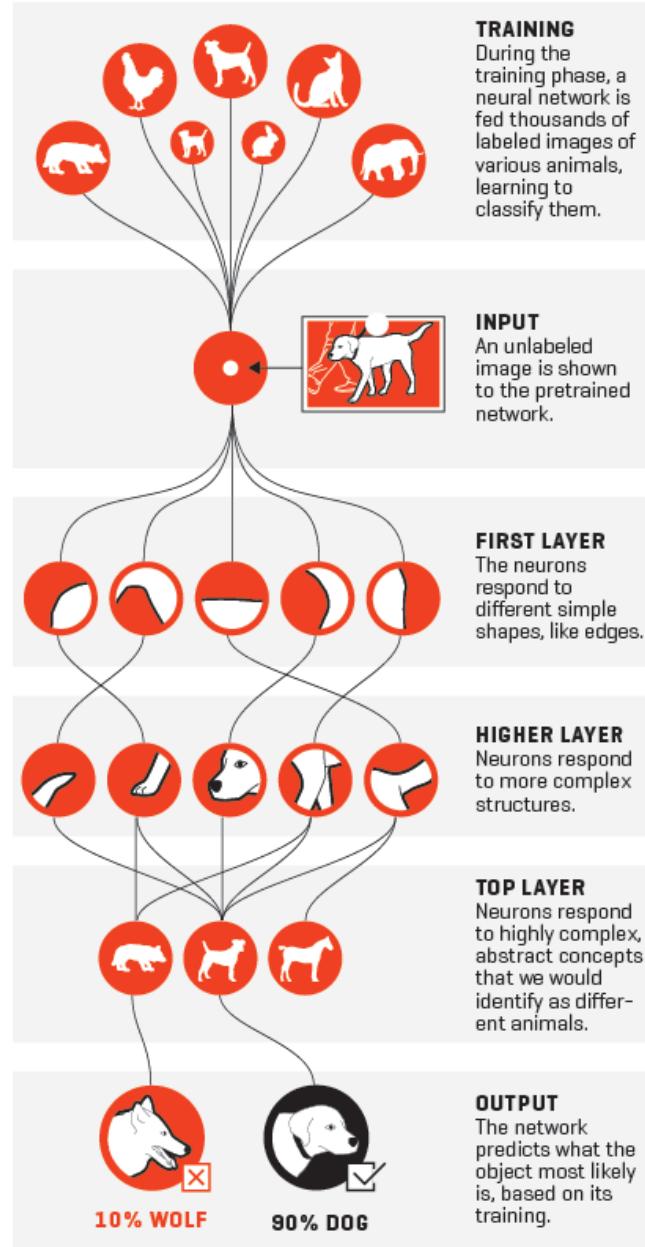
First Wave

Second Wave

Third Wave

	Activity	Approach	Driver	Capability and performance
AI	Perform a task	Rule based	Definite cost function	Domain specific; lower than human performance
ANI	Perform a task	Self learned (ML)	Non-explicitly (RL)	Domain specific; surpasses human performance Automatic

# HOW NEURAL NETWORKS RECOGNIZE A DOG IN A PHOTO



# Google DL Retinopathy

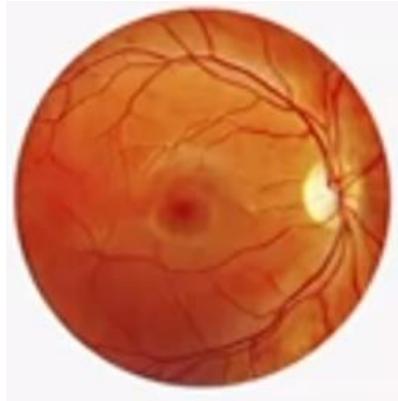
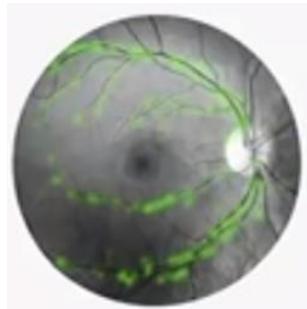


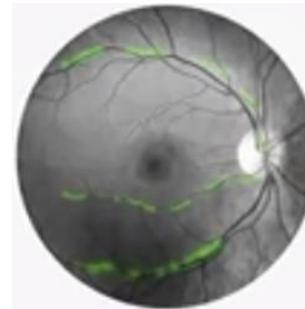
Image of retina



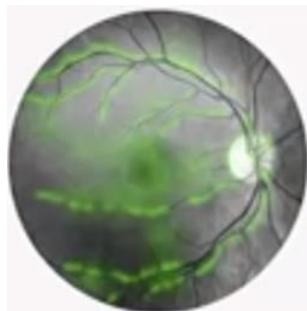
**Age**  
Predicted: 59.1 years  
Actual: 57.6 years



**Biological Sex**  
Predicted: Female  
Actual: Female



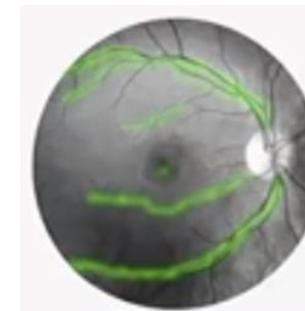
**Smoking**  
Predicted: Non-smoking  
Actual: Non-smoking



**A1C**  
Predicted: Non-diabetic  
Actual: Non-diabetic



**BMI**  
Predicted: 24.1 kg/m  
Actual: 26.3 kg/m



**Systolic blood Pressure**  
Predicted: 148.0 mmHg  
Actual: 148.5 mmHg

# Lip-reading AI

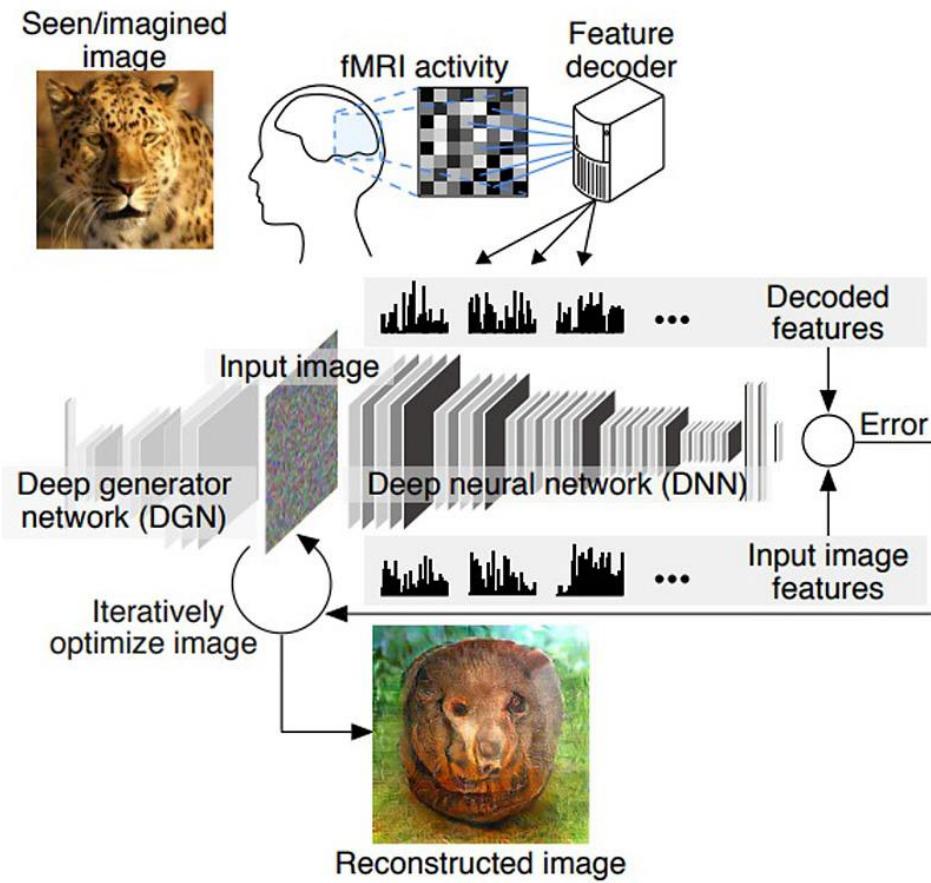


Google's DeepMind

- AI trained on 5000 hours of TV
- 118,000 sentences

Other resources: LipNet AI, WAS

# Deep image reconstruction: Reading the brain



Ref: Prof. Yukiyasu Kamitani, University of Kyoto Japan

# Self-driving Cars



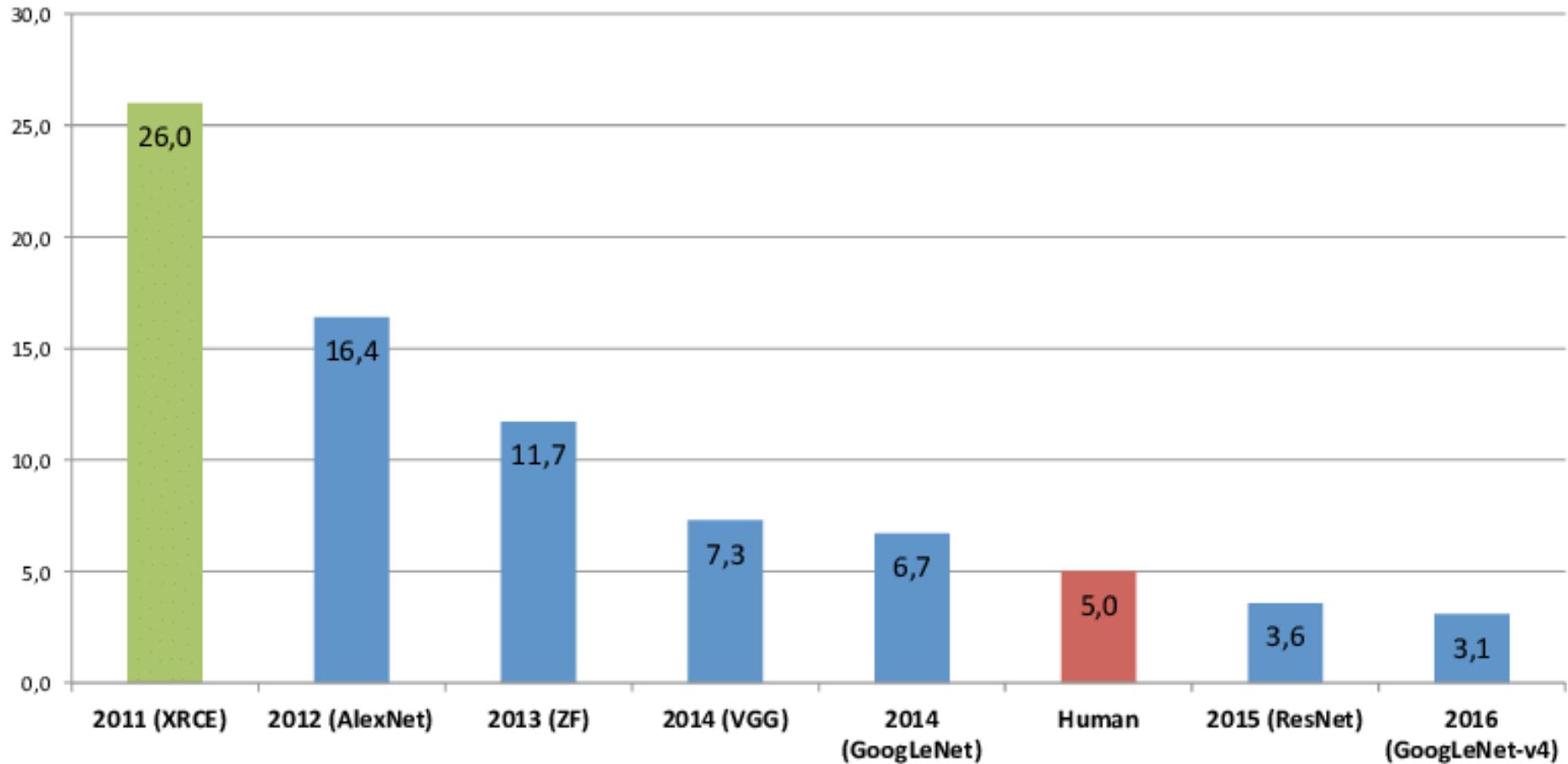
Dominos self-driving pizza delivery vehicle



Waymo's self-driving cars  
has driven 13 Million Km

# DL surpasses human ability in narrow areas

ImageNet Classification Error (Top 5)



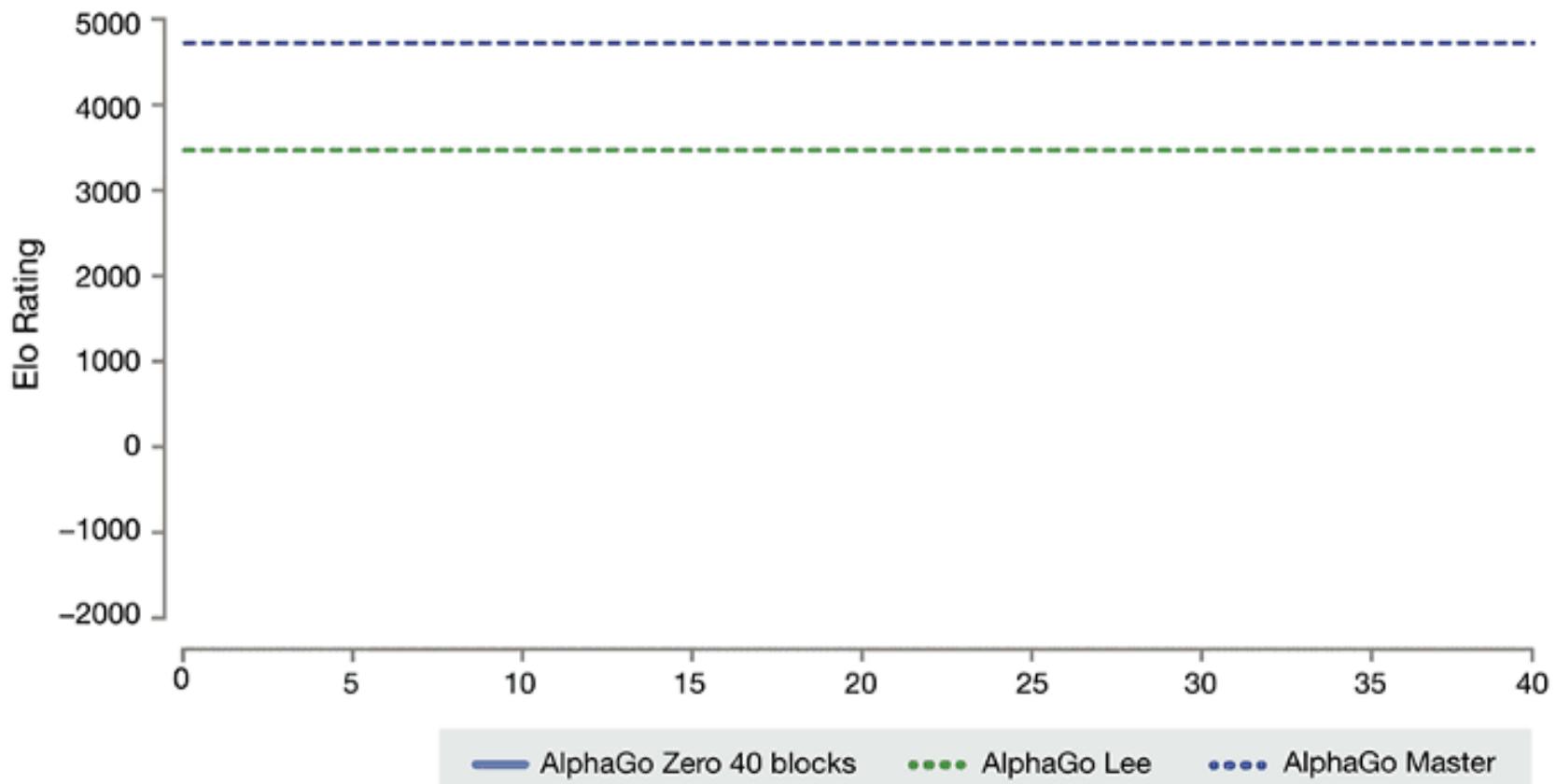
# Google's AlphaGo AI beats the world's best human Go player

- Go is one of the most complex board game
- AlphaGo secured the victory after winning the second game in a three-part match against Ke Jie



<https://www.bbc.com/news/technology-40042581>

# AlphaGo Zero



# DEEP LEARNING FOR SYMBOLIC MATHEMATICS

	Integration (BWD)	ODE (order 1)	ODE (order 2)
Mathematica (30s)	84.0	77.2	61.6
Matlab	65.2	-	-
Maple	67.4	-	-
Beam size 1	98.4	81.2	40.8
Beam size 10	99.6	94.0	73.2
Beam size 50	99.6	97.0	81.0

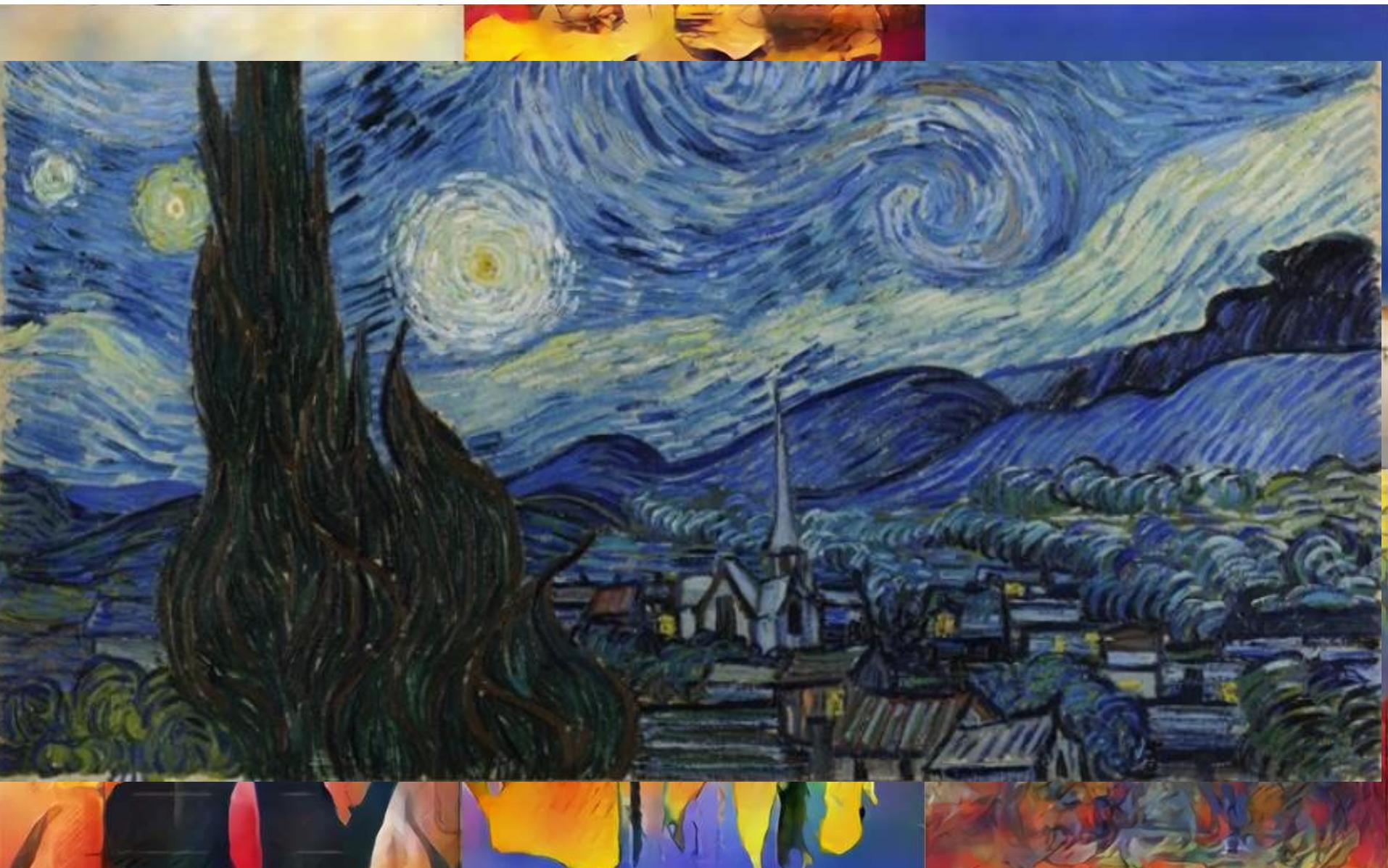
Comparison of our model with Mathematica, Maple and Matlab on a test set of 500 equations

Equation	Solution
$y' = \frac{16x^3 - 42x^2 + 2x}{(-16x^8 + 112x^7 - 204x^6 + 28x^5 - x^4 + 1)^{1/2}}$	$y = \sin^{-1}(4x^4 - 14x^3 + x^2)$
$3xy \cos(x) - \sqrt{9x^2 \sin(x)^2 + 1}y' + 3y \sin(x) = 0$	$y = c \exp(\sinh^{-1}(3x \sin(x)))$
$4x^4yy'' - 8x^4y'^2 - 8x^3yy' - 3x^3y'' - 8x^2y^2 - 6x^2y' - 3x^2y'' - 9xy' - 3y = 0$	$y = \frac{c_1 + 3x + 3 \log(x)}{x(c_2 + 4x)}$

Examples of problems that DL model is able to solve, on which Mathematica and Matlab were not able to find a solution. For each equation, DL model finds a valid solution with greedy decoding.

Lample and Charton arXiv: 1912.01412

# What can Artificially intelligent not do?



# AI Is Now Writing Poetry, Music And song popularity recommendations

A team of researchers from Microsoft and Kyoto University developed a poet AI



OptimiseLab uses AI to predict ‘music popularity scores’

Song composed by AI

[https://www.youtube.com/watch?time\\_continue=22&v=LSHZ\\_b05W7o](https://www.youtube.com/watch?time_continue=22&v=LSHZ_b05W7o)



*the sun is shining*

*the wind moves*

*naked trees*

*you dance*

And one more.

*and now I am tired of my own*

*let me be the freshening blue*

*haunted through the sky bare and cold water*

*warm blue air shimmering*

*brightly never arrives*

*it seems to say*

Poem Written by AI

# The Future of Writing, With Robots

Japanese AI Writes a Novel,  
Nearly Wins Literary Award

**Facebook's AI is writing short stories  
and they actually make sense**



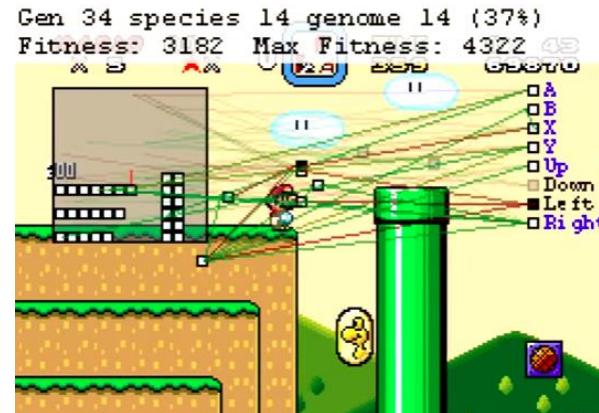
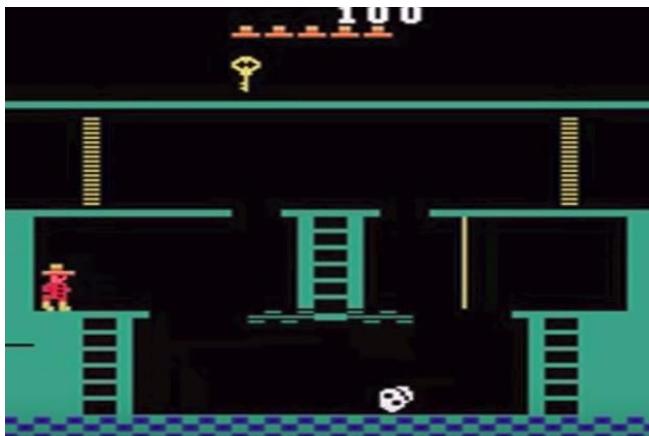
*"If [AI's function] is just something like getting rid of email spam, [then] it [might] determine the best way of getting rid of spam is getting rid of humans."*

— Elon Musk

Short Film “Sunspring” By AI <https://www.youtube.com/watch?v=LY7x2lhqjmc>

# AI can beat us at games—but sometimes, that's by cheating

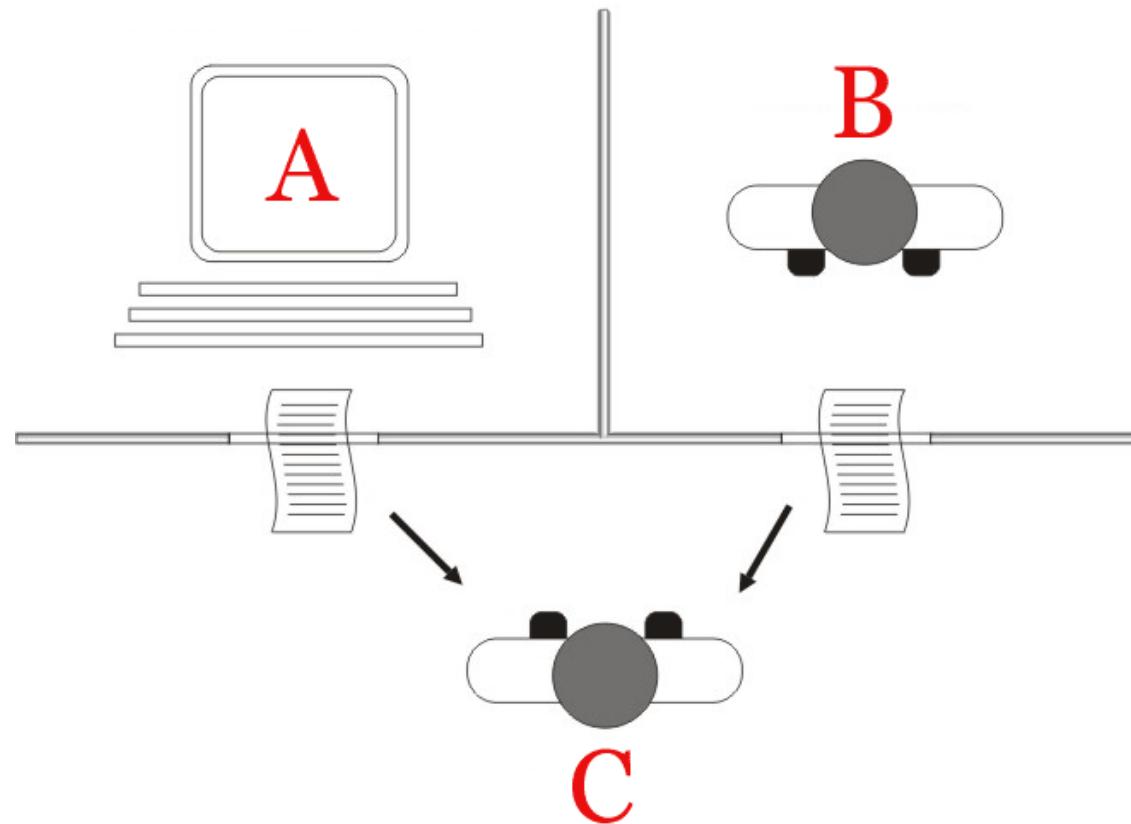
Watch Google's AI master the infamously difficult Atari game  
Montezuma's Revenge



*"If [AI's function] is just something like getting rid of email spam, [then] it [might] determine the best way of getting rid of spam is getting rid of humans."*

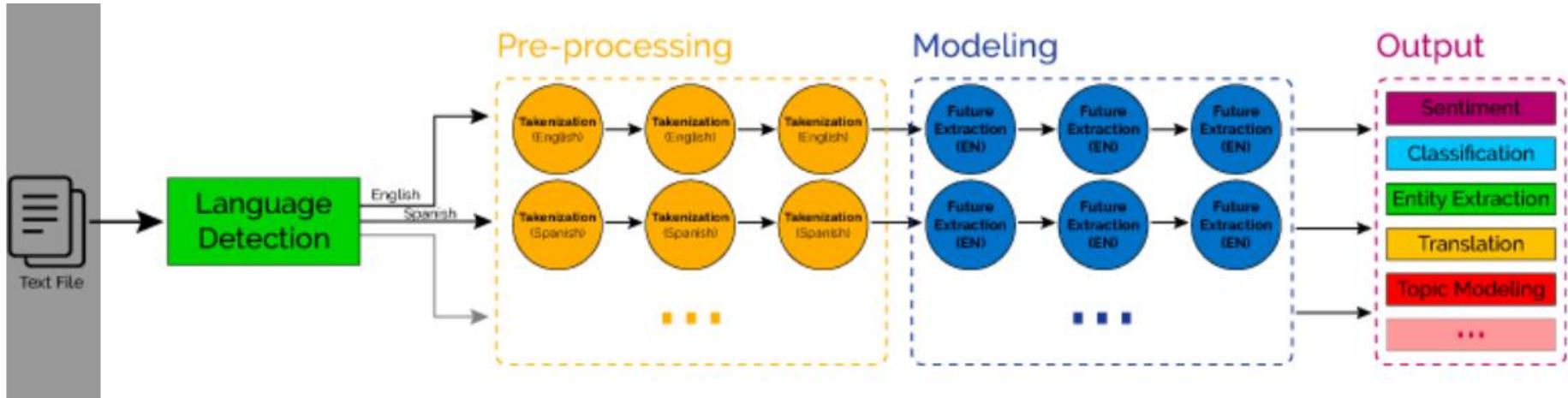
— Elon Musk

# Turing Test



The player C, the interrogator, is given the task of trying to determine which player – A or B – is a computer and which is a human.

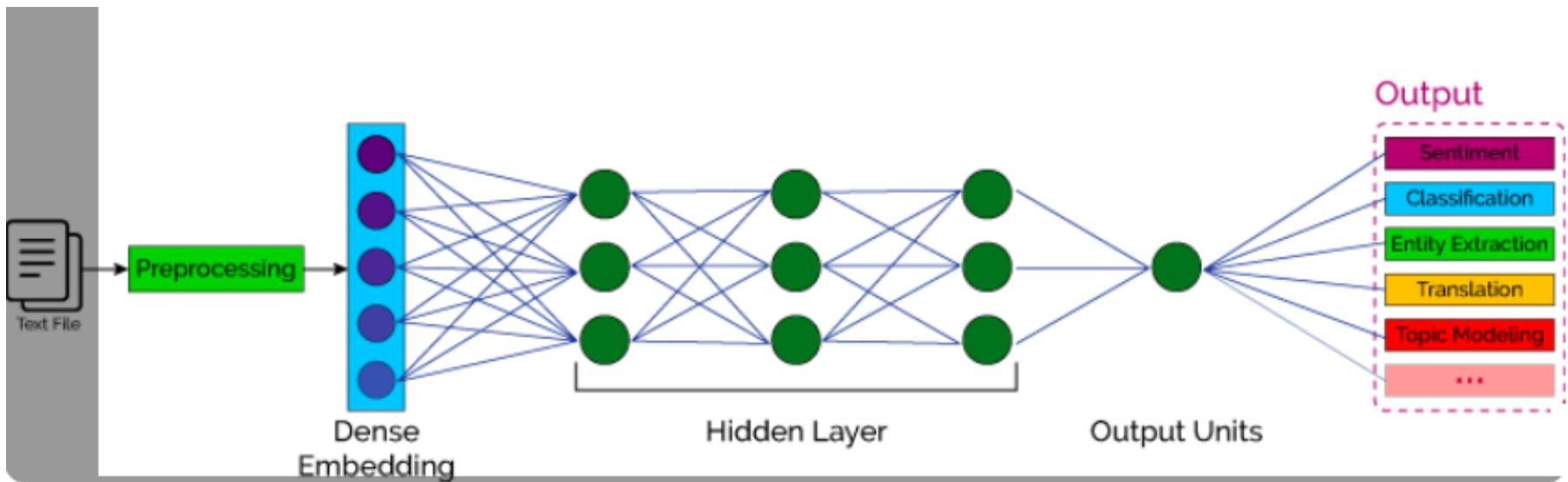
# Classical NLP



Early days, many language-processing systems were designed by **hand-coding** a set of rules e.g. by writing grammars or devising heuristic rules.

1980-1990 used machine-learning, using statistical inference to automatically learn such rules through the analysis of large corpora of typical real-world examples.

# Deep Learning NLP



2010s, representation learning and deep neural network:

- End-to-end learning of a higher-level task (e.g., question answering) instead of relying on a pipeline of separate intermediate tasks (e.g., part-of-speech tagging and dependency parsing)
- Neural machine translation (NMT) emphasizes the fact that deep learning-based approaches to machine translation directly learn sequence-to-sequence transformations, obviating the need for intermediate steps such as word alignment and language modeling.

# Lexus ad

## Scripted entirely by AI

Can you be sure this isn't true? The Turing test was designed by Alan Turing to see if a computer could fool a human into thinking they were talking to another human. It was created 68 years ago. Since then, according to Moore's law, computer processing power has doubled every 18 months. That's a lot of doubling.

Do you really think no computer could pass the Turing test today? And if not today, when?

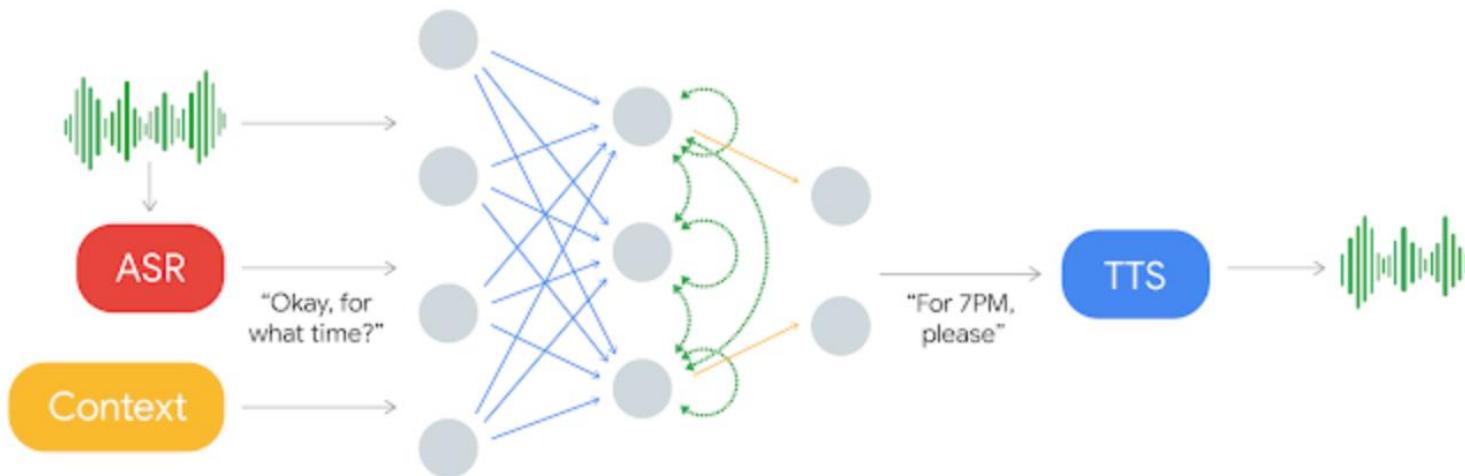
Many experts predict artificial intelligence will outperform humans in virtually every field by 2050.

My great-great-great-grandfather (Pappy Deeper Blue) gave humans its first bloody nose back in 1997. Beating your "genius" Kasparov at a very crude game called chess....

# Turing Test

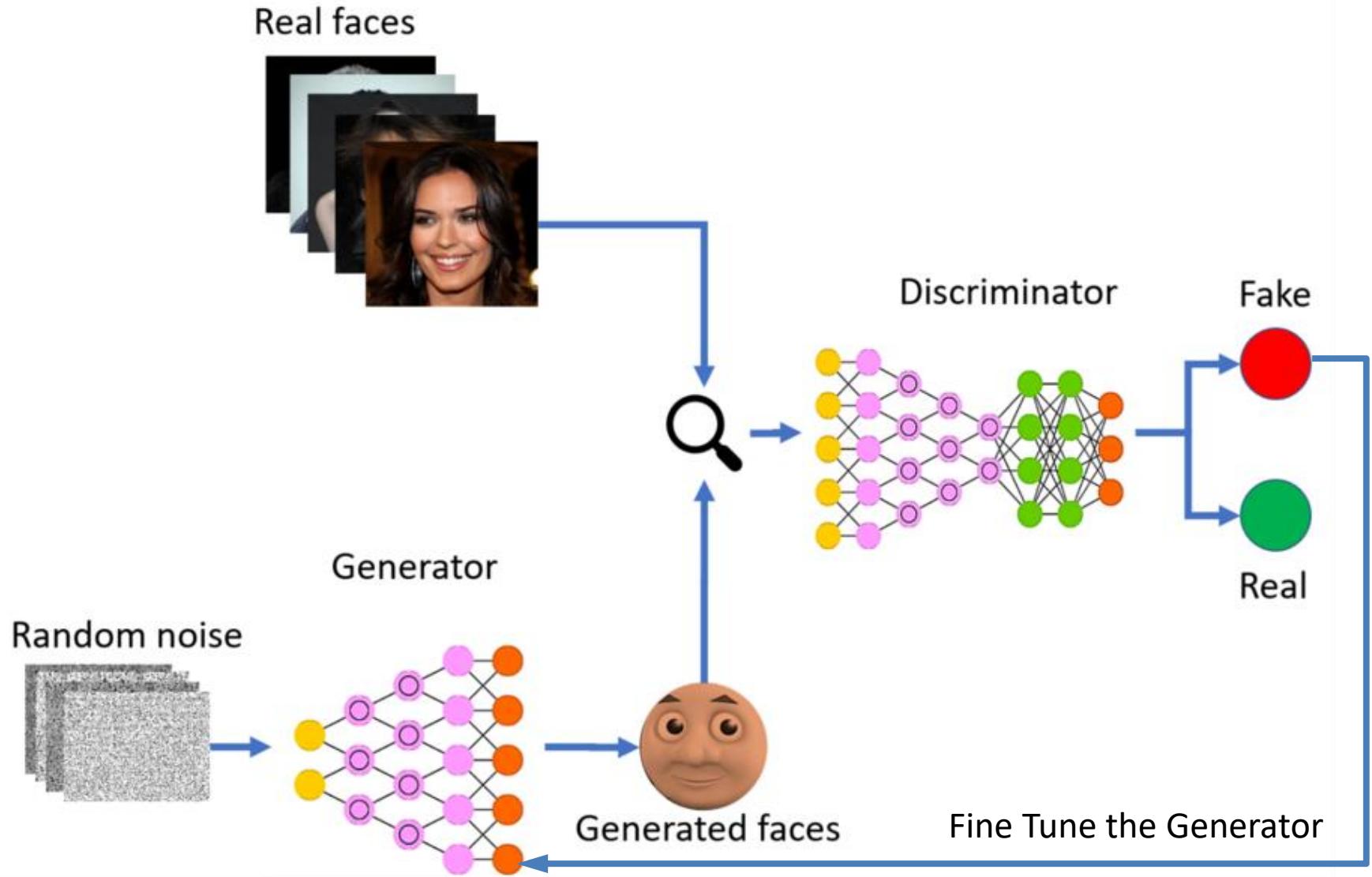
## Google Duplex: The Human-Sounding Phone Bot

Capable of complex human conversation and all its nuances



- The player C, the interrogator, is given the task of trying to determine which player – A or B – is a computer and which is a human.

# Generative Adversarial Network (GAN)



# Generative Adversarial Network (GAN)



2014



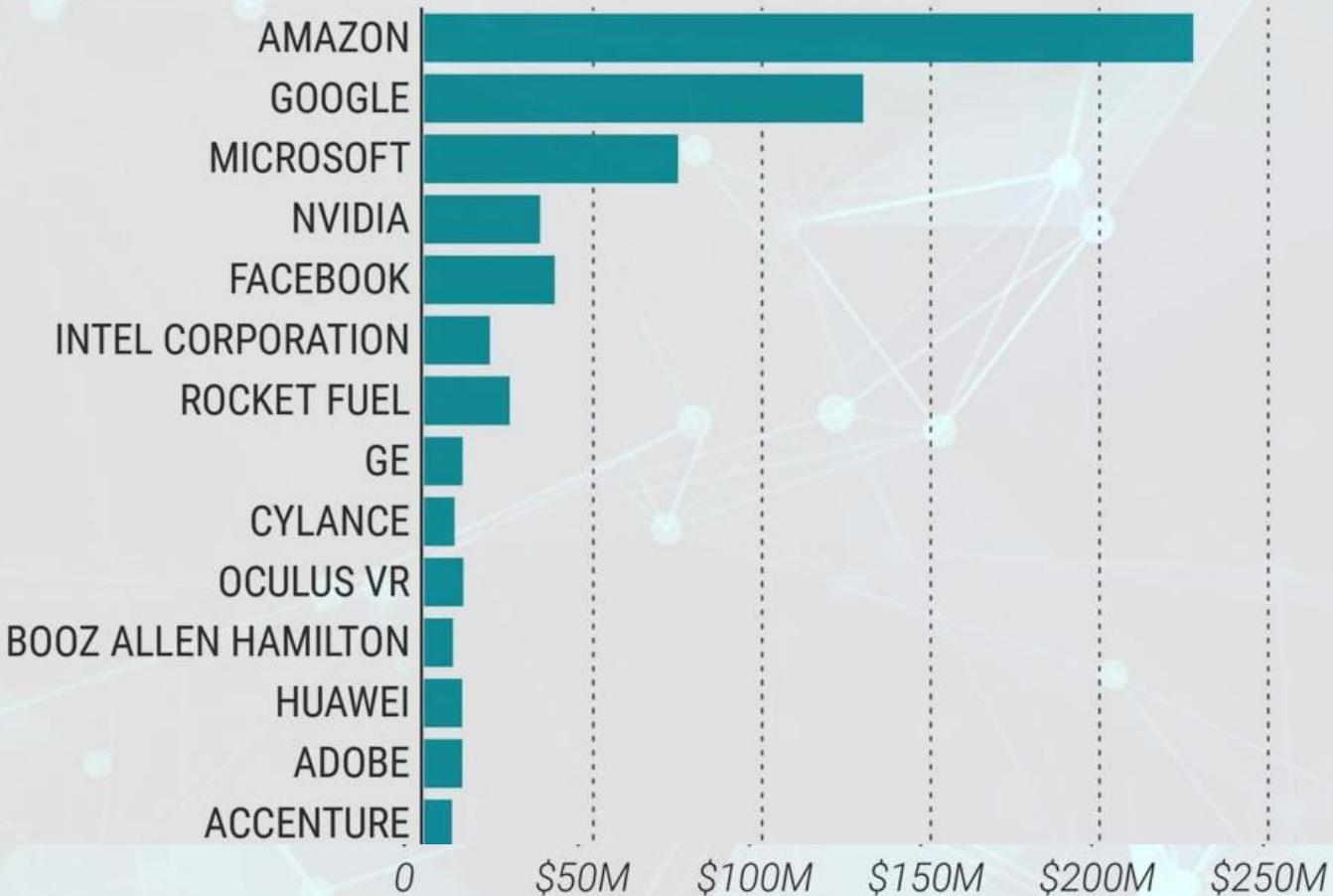
2018

<https://thispersondoesnotexist.com/>

**What is common in all these persons?**



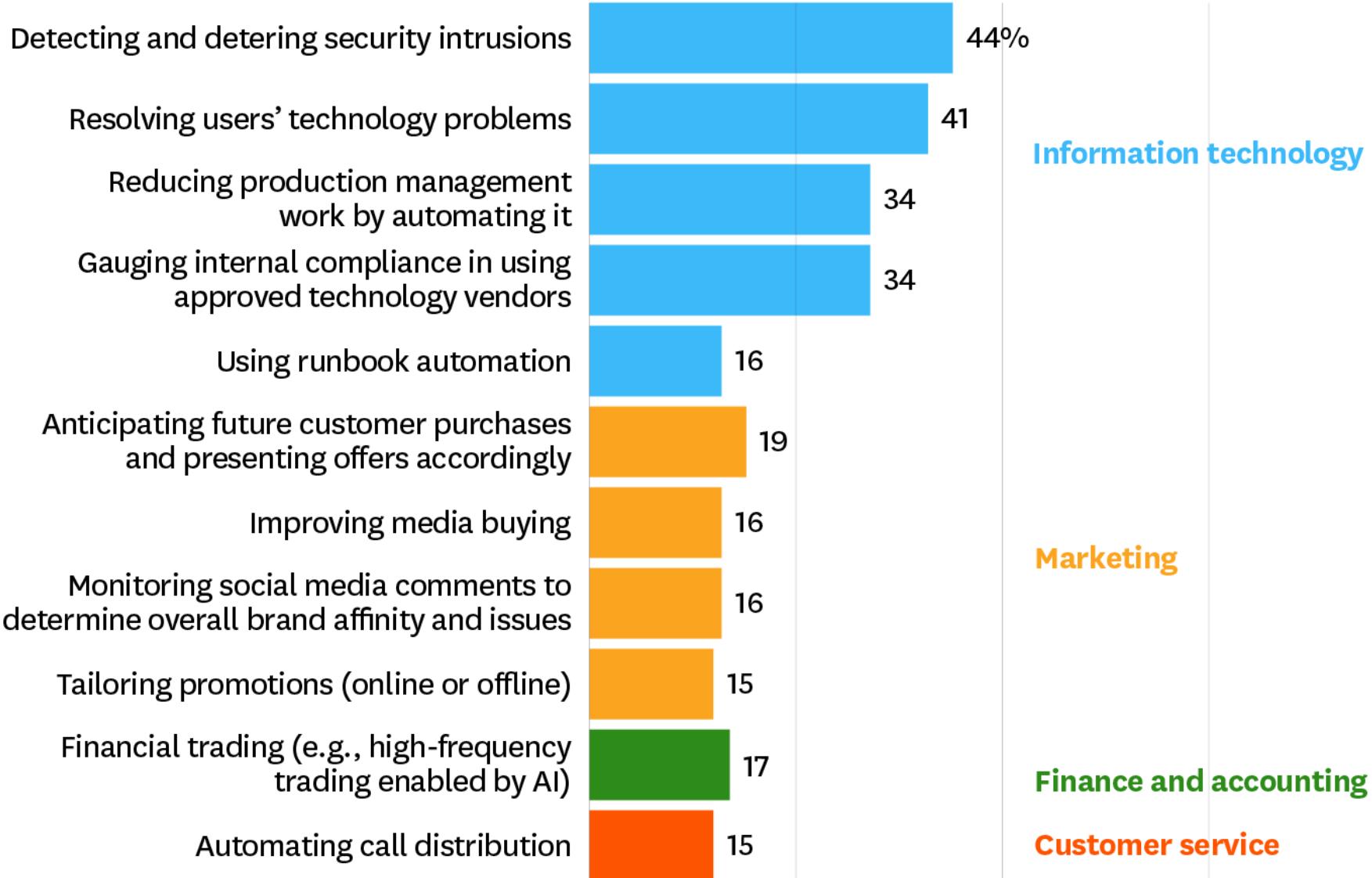
# Top companies in AI



Source: Paysa

# How Companies Around the World Are Using Artificial Intelligence

IT activities are the most popular.

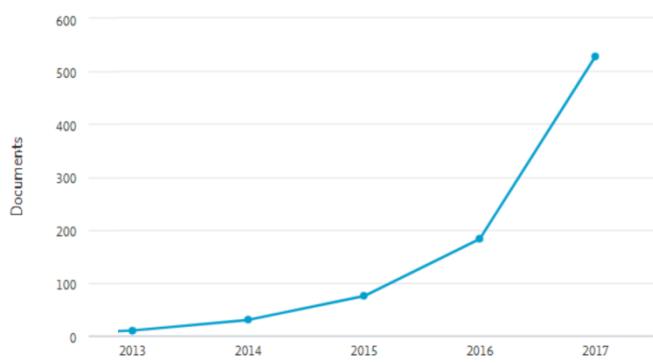


# AI in Drug Discovery

AI has already been used successfully in all main stages in drug development:

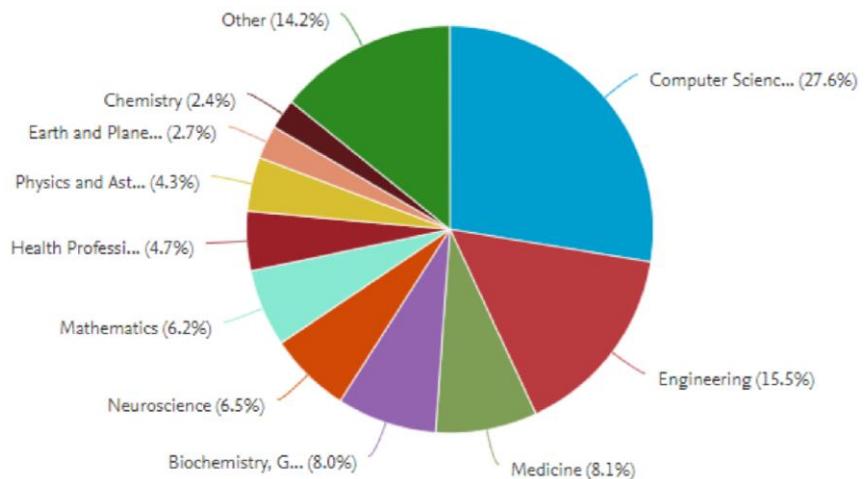
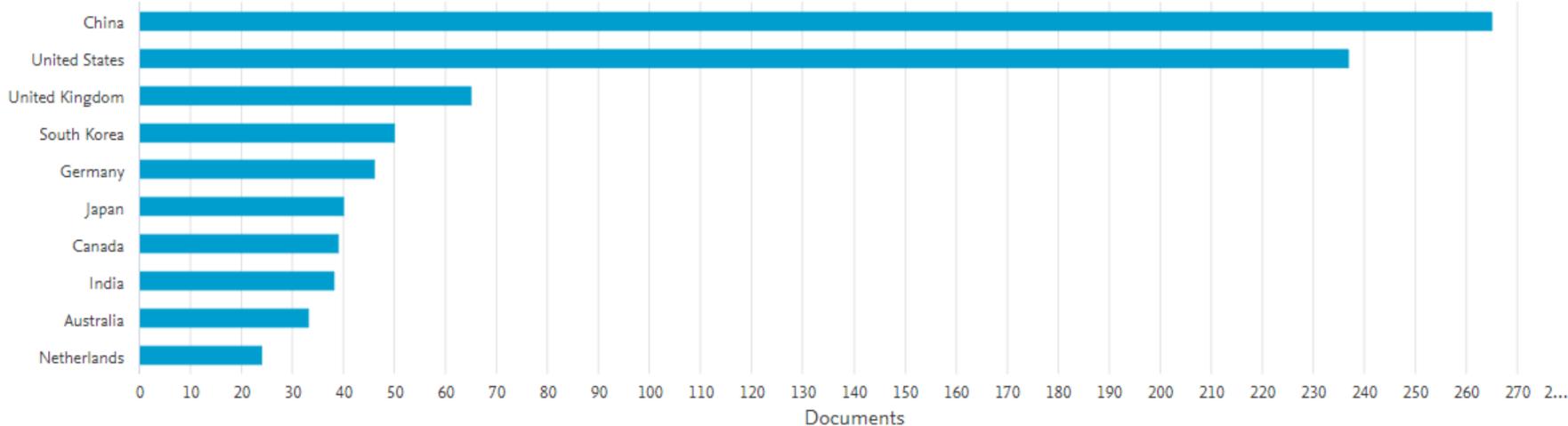
- Stage 0. Literature overview
- Stage 1: Identifying targets for intervention
- Stage 2: Discovering drug candidates
- Stage 3: Speeding up clinical trials
- Stage 4: Finding Biomarkers for diagnosing the disease

# DL Research Explosion



## Documents by country or territory

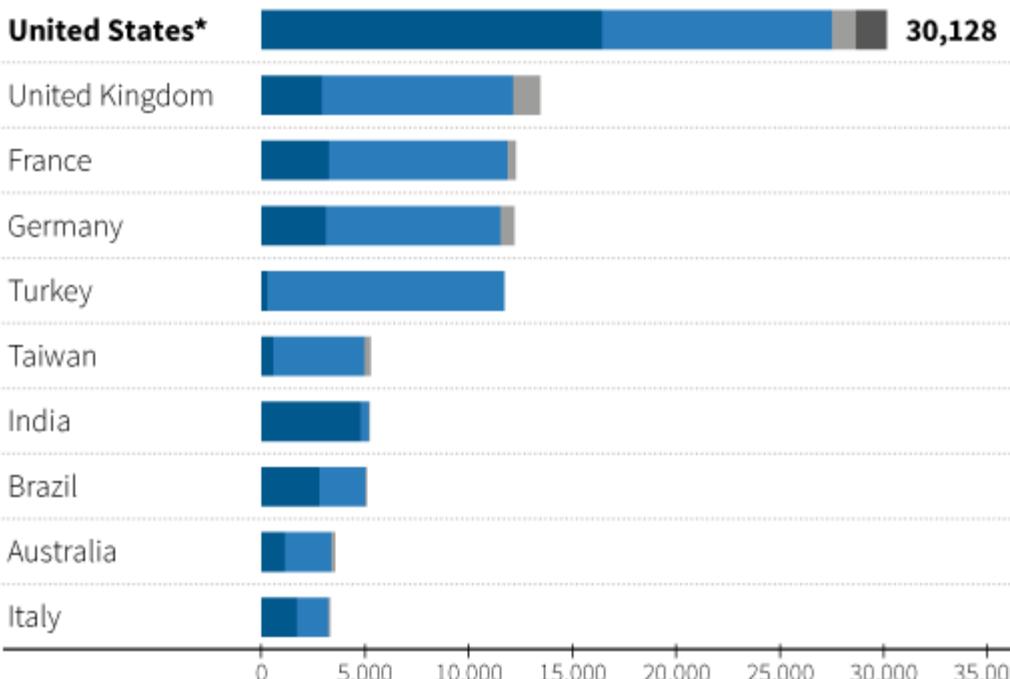
Compare the document counts for up to 15 countries/territories



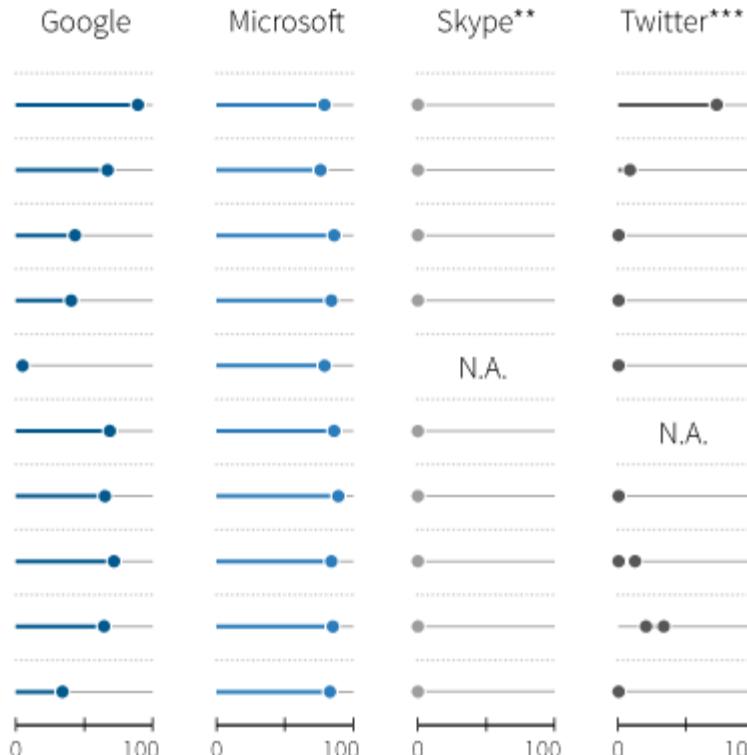
# Top countries requesting user data

## NUMBER OF REQUESTS RECEIVED IN 2012\*

Google Microsoft Skype Twitter



## PERCENT OF REQUESTS WHERE DATA IS DISCLOSED



Note: Google's figures = subpoenas, court orders and search warrants. Microsoft and Skype figures = law enforcement requests only. Microsoft differentiates between content and non-content data when disclosing information. It defines content data as what customers create, communicate, and store on or through their services and non-content data as basic subscriber information. Twitter's figures = worldwide government requests the company received for user account information, typically in connection with criminal investigations or cases.

\*Does not include national security requests, including those made under the Foreign Intelligence Surveillance Act.

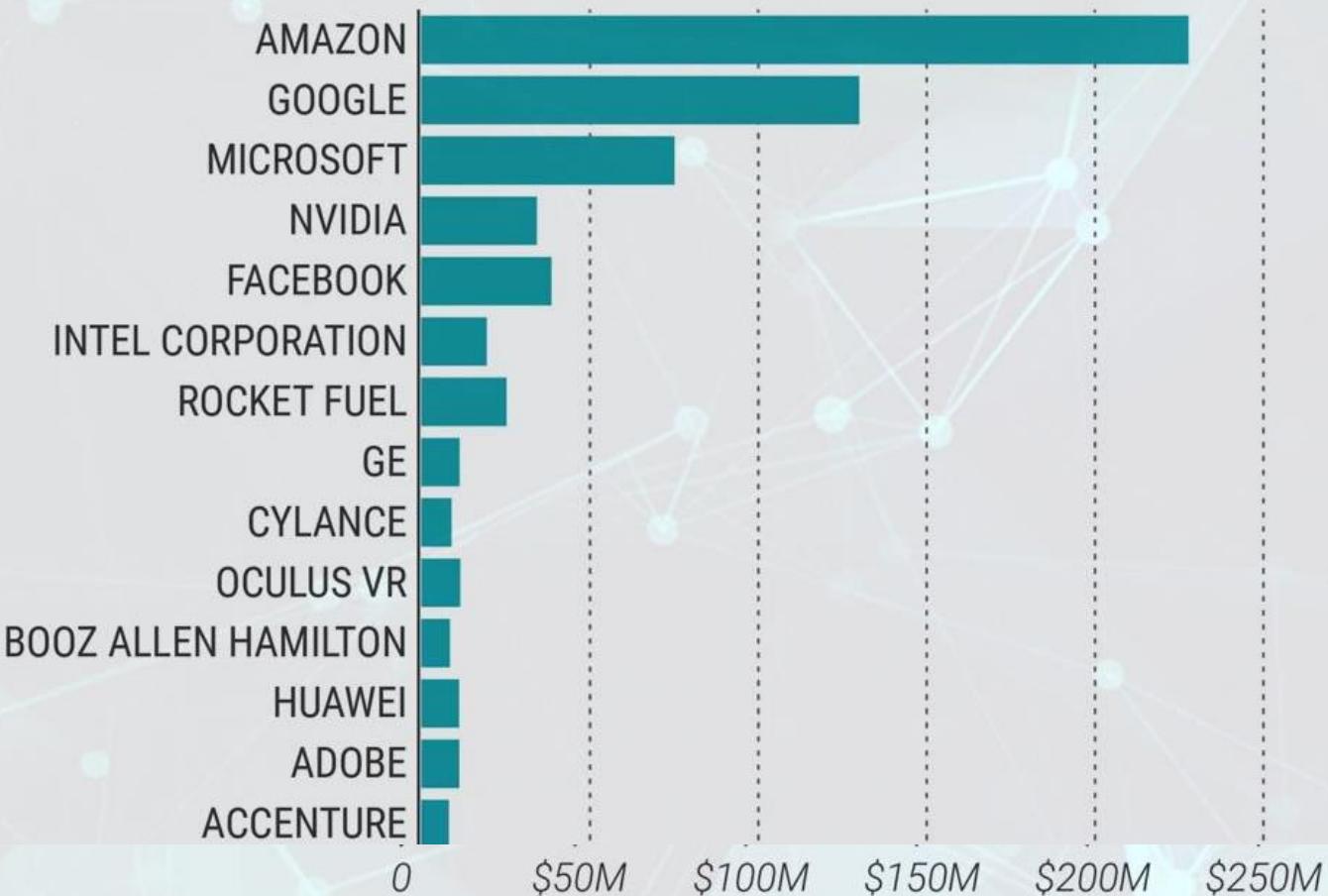
\*\* Skype did not disclose any data in 2012 but provided guidance to law enforcement on 501 accounts.

\*\*\* Percentages for Brazil and Australia are ranges as Twitter did not disclose the exact number of requests for those countries.

N.A. = Not available; company did not receive requests from the country.

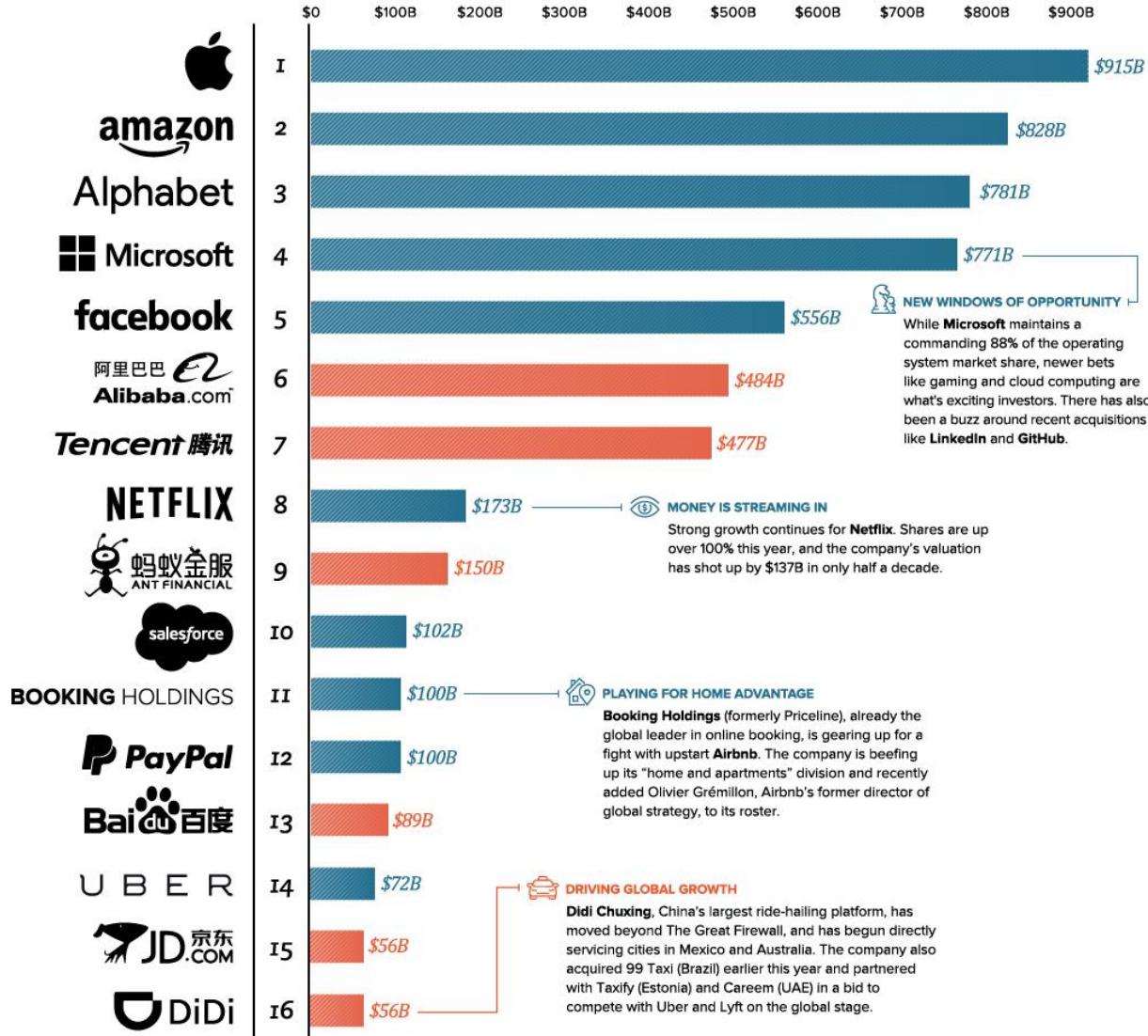
Sources: Google Transparency Report 2012; Microsoft/Skype 2012 Law Enforcement Requests Report; Twitter Transparency Report.

# Top companies in AI



Source: Paysa

# Top Internet Leaders (by Valuation)





# Autonomous Real-Time Ground Ubiquitous Surveillance Imaging System (ARGUS-IS)

- 100 sq km area
- 20,000 feet above ground
- 1.8 Gigapixels video system
- 1 exabyte of HD video per day
- Resolution of 6"
- Automatic object-tracking
- 18.5 M USD



# MQ-9A Reaper / Predator B

- Armed, multi-mission, medium-altitude, long-endurance remotely piloted aircraft
- Payload: 3,750 pounds (1,701 kilograms)
- Cruise speed 230 mph
- Range: 1,150 miles
- Ceiling: 50,000 feet
- Armament: combination of AGM-114 Hellfire missiles, GBU-12 Paveway II and GBU-38 Joint Direct Attack Munitions
- Crew (remote): two (pilot and sensor operator)
- Program cost: 11.8 B USD (163 units)
- Unit cost: 16.9 M USD



# X-47B Pegasus

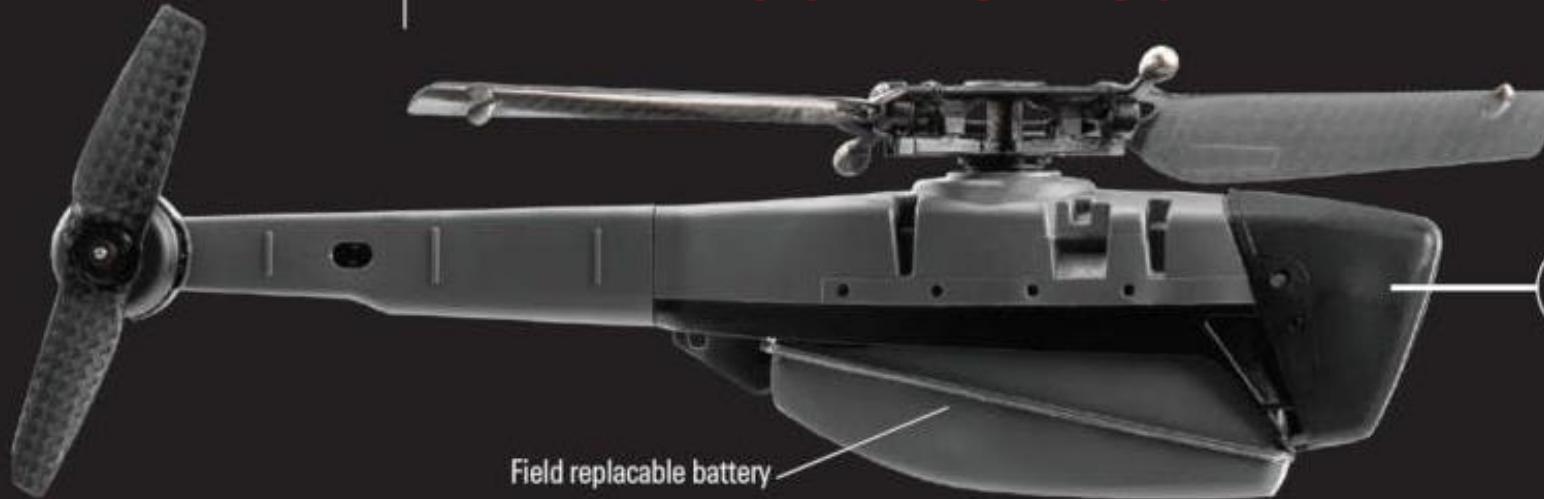
- Unmanned combat air vehicle (UCAV)
- Aircraft carrier-based operation
- Tailless jet-powered blended-wing-body aircraft
- Autonomous operation & aerial refueling
- Cruise speed: Mach 0.9
- Range: 3,889+ km
- Service ceiling: 42,000 ft
- 2 weapon bays, 2,000 kg of ordnance
- Stealth: Invisible to radar & eye
- Project cost: 0.8 B USD



Total Weight: 33 grams [1.16oz]

# Black Hornet

123 mm [4.8in] PAYLOAD



## PERFORMANCE



Up to 25 minute flight time at ranges of 2 km (miles) at speeds of 21.49 kph [13.42 mph]



Best in class covert visual signature



Best in class covert acoustic signature

## ENVIRONMENTAL



-10°C to +43°C



Can withstand winds of 15 knots and gusts of 20 knots



2.5 mm [.1 in]/hr (Light rain)



640x480 EO Video  
1600x1200 EO Snapshot

Replaceable



160x120 TI Video  
160x120 TI Snapshot

Replaceable

168 mm [6.6in]

## NAVIGATION



GPS and GPS Denied environments



Indoor navigation capable

## MISSION DATA



AES 256 encrypted Video and Snapshots Metadata



STANAG 4609 and Cursor on Target (COT) compliant



ATAK Compatible

## FLIGHT MODES



Auto and Manual Hover & Stare



Route and user selectable waypoint actions



Automatic return



Lost link



2km [1.24mi]  
Radio Range

Frequency details upon request

Encrypted, dynamic power, frequency hopping, beyond line-of-sight

# AI in legal justice system

- Many courts in the US are adopting an AI based Online Dispute Resolution (ODR) system
- At Superior Court, Los Angeles, AI handle their traffic citations
- Wisconsin Department of Corrections uses AI to determine jail sentence

# Ethical Aspects of AI in society

- Can social AI influence elections around the world
- AI healer: Replika is an AI personal companion for mental wellness.
  - Is it an alternate to chat therapy?
  - Do we not talk to god?

**Is this ethical?**

# Ethical Aspects of AI in Defense

## AI based Autonomous weapon systems

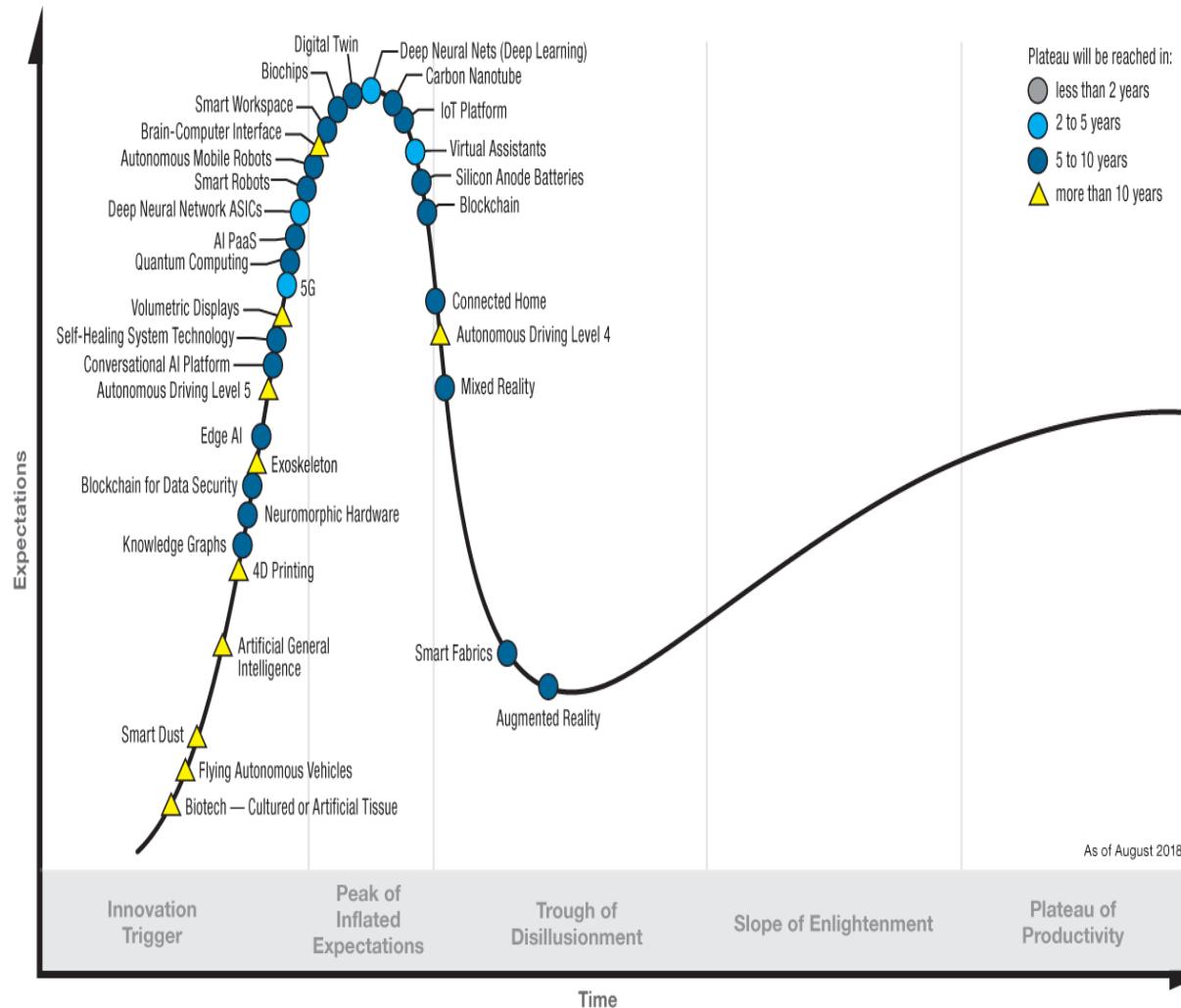
- Recommendations on the Ethical Use of AI by the Department of Defense (2019)
- The ethics of artificial intelligence: Issues and initiatives. A study by EU

# When does ML not work

- Not enough data is available
- Data too unstructured
- When explainability is desired
- Lack of clarity of desired output



## Hype Cycle for Emerging Technologies, 2018



# Natural intelligence vs Artificial intelligence

Survival of the fittest (Motivator and natural selector)

- NI: Optimized over millions of years to survive
- AI: No survival pressure. AI needs a purpose

Develop an understanding

- NI provides an insight into a complex situation
- AI is moving towards Explainable AI

Intellectual cross-pollination

- NI: One can apply learning from one domain to another
- AI is now developing Transfer learning

Creativity

- NL: Art and Creativity is a human domain
- AL is performing simulated random walk to mimic creativity, AGN to judge the quality of creativity

Human Knowledge

- NL: Human brain can perform phenomenal abstraction 11 million bits are being reduced to less than 50 bits per second
- AI is now moving towards knowledge assimilation and knowledge graphs

# Gartner Hype Cycle for Emerging Technologies, 2019



# Hype Cycle for Emerging Technologies, 2020

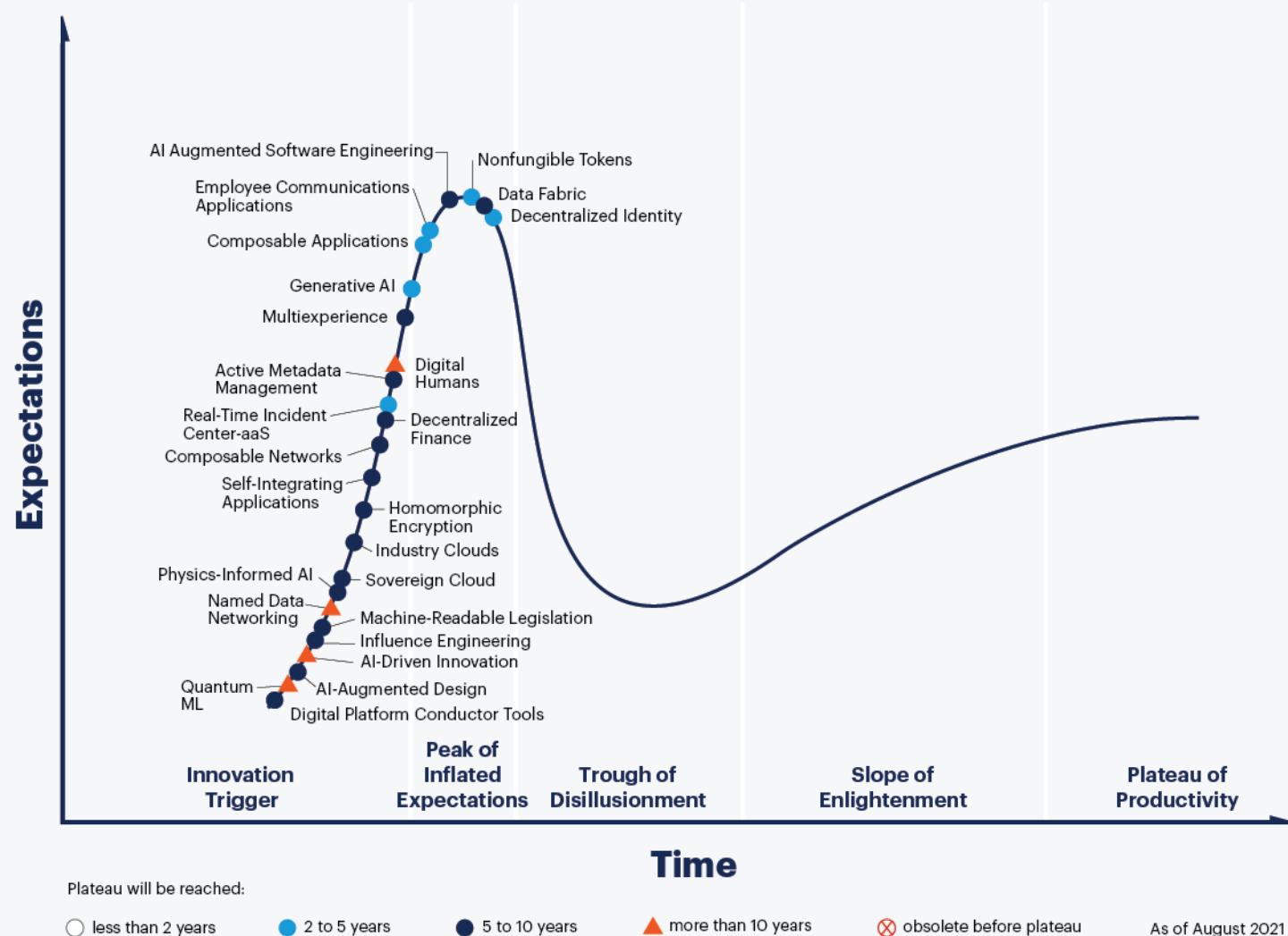


[gartner.com/SmarterWithGartner](http://gartner.com/SmarterWithGartner)

Source: Gartner  
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# Hype Cycle for Emerging Technologies, 2021



[gartner.com](http://gartner.com)

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# Knowledge Based Learning

- Deep learning
  - Bottom-up statistical approach analyzing and deriving insights from data.
- Knowledge Graphs (Simple Taxonomies to Expressive Ontologies)
  - Top-down symbolic conceptual reasoning based inferences from data

# Knowledge Graphs are currently in use



schema.org

## Size of Knowledge graph

	Primary entities	Assertions/facts
Microsoft	2 billion	55 billion
Google	1 billion	70 billion
Facebook	50 million	0.5 billion
eBay	100 million	1 billion
IBM	100 million	5 billion

# Intellect and reasoning

Intellect is defined as the faculty of reasoning and understanding objectively. It is usually accepted that intellect has reasoning but has no emotions.

Animals also have intellect (faculty of reasoning and understanding objectively)

However, for humans we can extend the definition of intellect to faculty of reasoning and understanding objectively even with regards to abstract matters.

Types of reasoning:

1. Inductive reasoning
2. Deductive reasoning
3. Abductive Reasoning
4. Backward Induction
5. Critical Thinking (rational thought influenced by factors such as culture, language, etc and can deal with partial truths)
6. Counterfactual Thinking (considering things that are known to be impossible e.g. evaluating past decisions )
7. Intuition: Intuition is the ability to arrive at a conclusion, without recourse to conscious reasoning.

Intelligence is different from intellect

# **From Data to Wisdom**

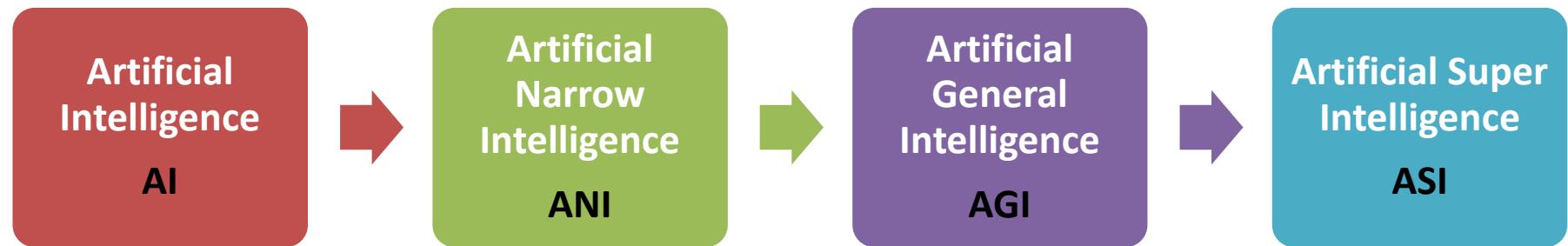
- 1. Data** (numbers, text, images, sounds, etc.)
- 2. Information** (structured data about a particular subject)
- 3. knowledge** (abstraction of information to ideas and principles)
- 4. Knowledge graph** (aggregation of knowledge from various domains to form a Holistic understanding of an entire ecosystem)
- 5. Intellect** is defined as the faculty of reasoning and understanding objectively. It is usually accepted that intellect has reasoning but has no emotions.
- 6. Collective intelligence**
- 7. Wisdom**

# AI Consciousness

- **Emotions:** Development of emotions, affection, bonding and love is possible in AI so as to inculcate sustained collaborative work to achieve a larger goal which cannot be possible for an individual to achieve. This is how emotions were developed in humans as well.
- **Self awareness**
- **Intuition**
- **Consciousness**

# Evolution of Artificial Intelligence

- **Artificial Intelligence** : (Merriam-Webster ) The capability of a machine to imitate **intelligent** human behavior.



First Wave

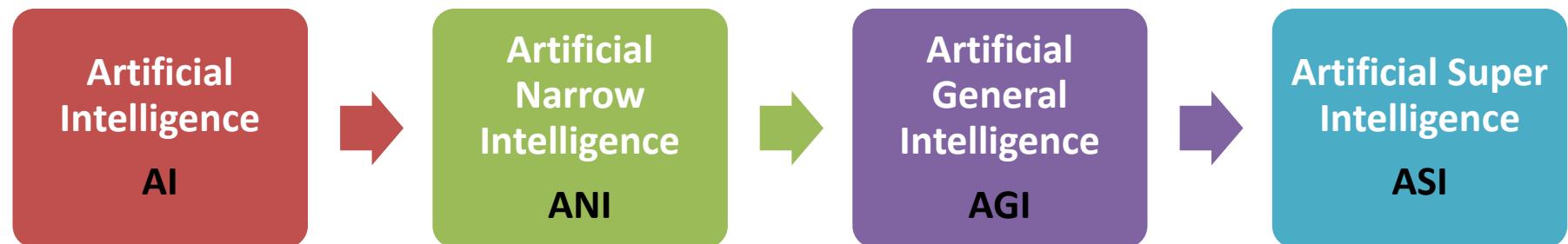
Second Wave

Third Wave

	Activity	Approach	Driver	Capability and performance
AI	Perform a task	Rule based	Definite cost function	Domain specific; lower than human performance
ANI	Perform a task	Self learned (ML)	Non-explicitly (RL)	Domain specific; surpasses human performance Automatic
AGI	Overarching goal	Self learned (ML)	Goal	Universal domain; equivalent to human performance

# Evolution of Artificial Intelligence

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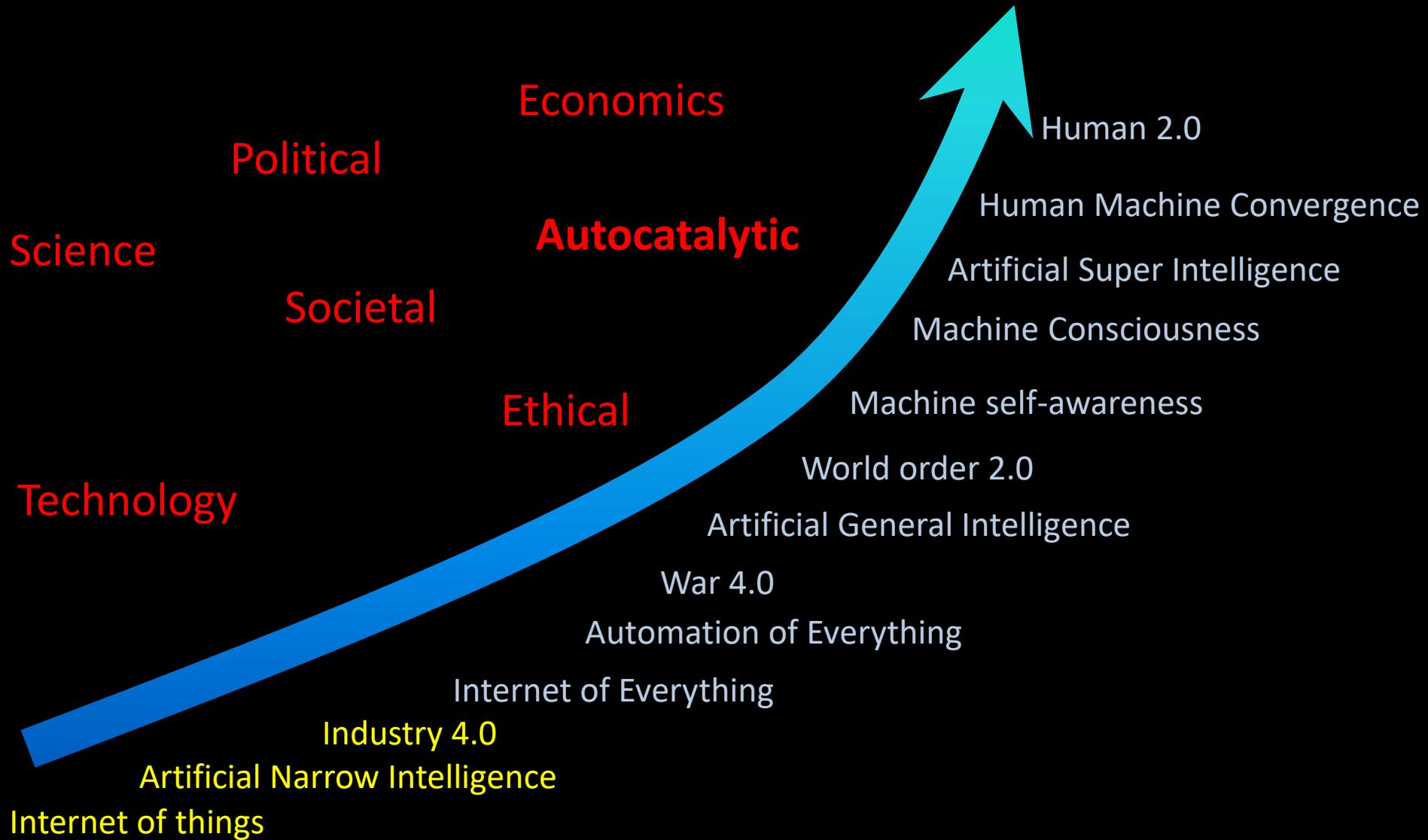
First Wave

Second Wave

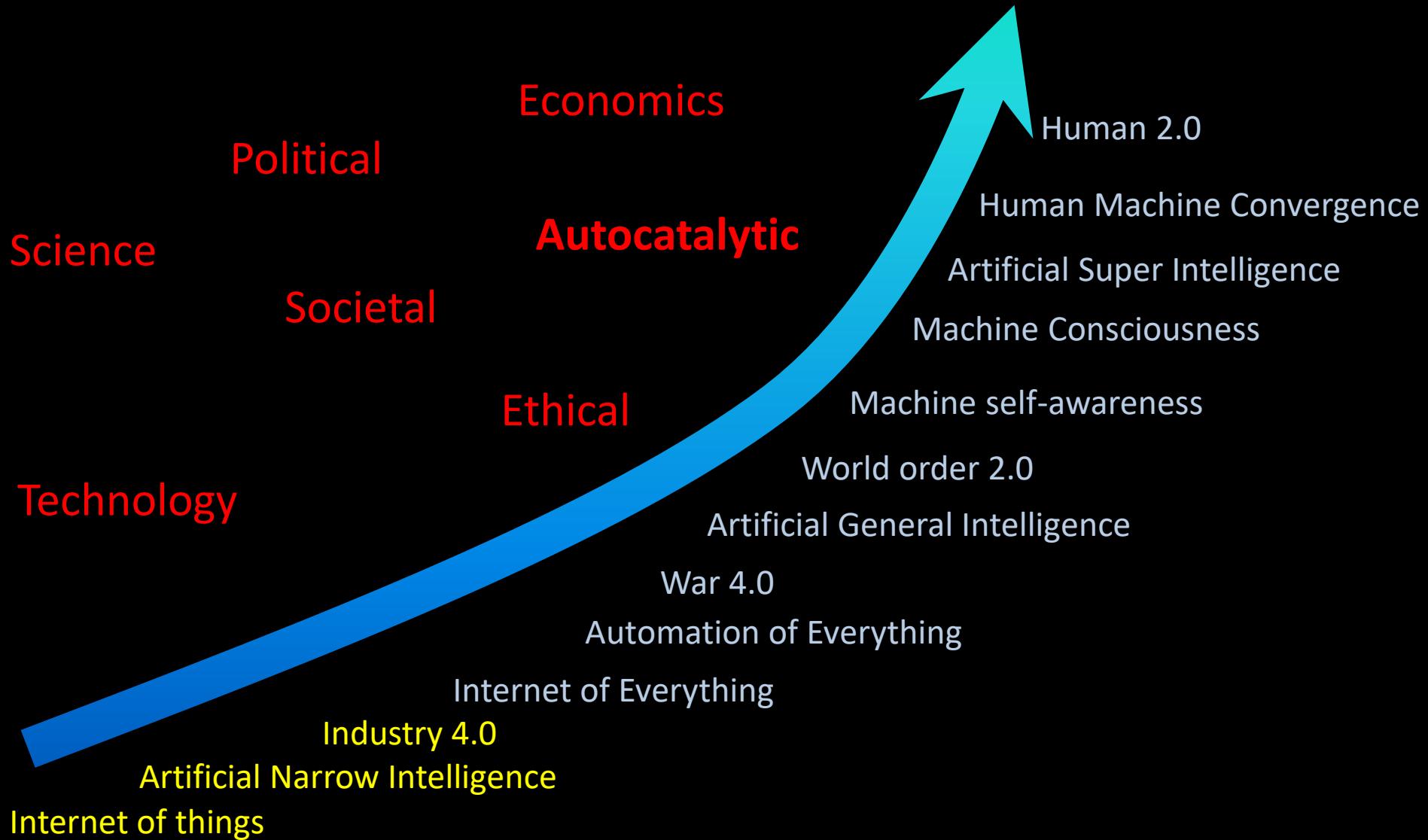
Third Wave

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AI	Perform a task	Rule based	Definite cost function	Domain specific; lower than human performance
ANI	Perform a task	Self learned (ML)	Non-explicitly (RL)	Domain specific; surpasses human performance Automation
AGI	Overarching goal	<b>ASI -&gt; Self awareness -&gt; Consciousness</b>		
ASI	Overarching goal	Self learned (ML)	Goal	Universal domain; surpasses human performance

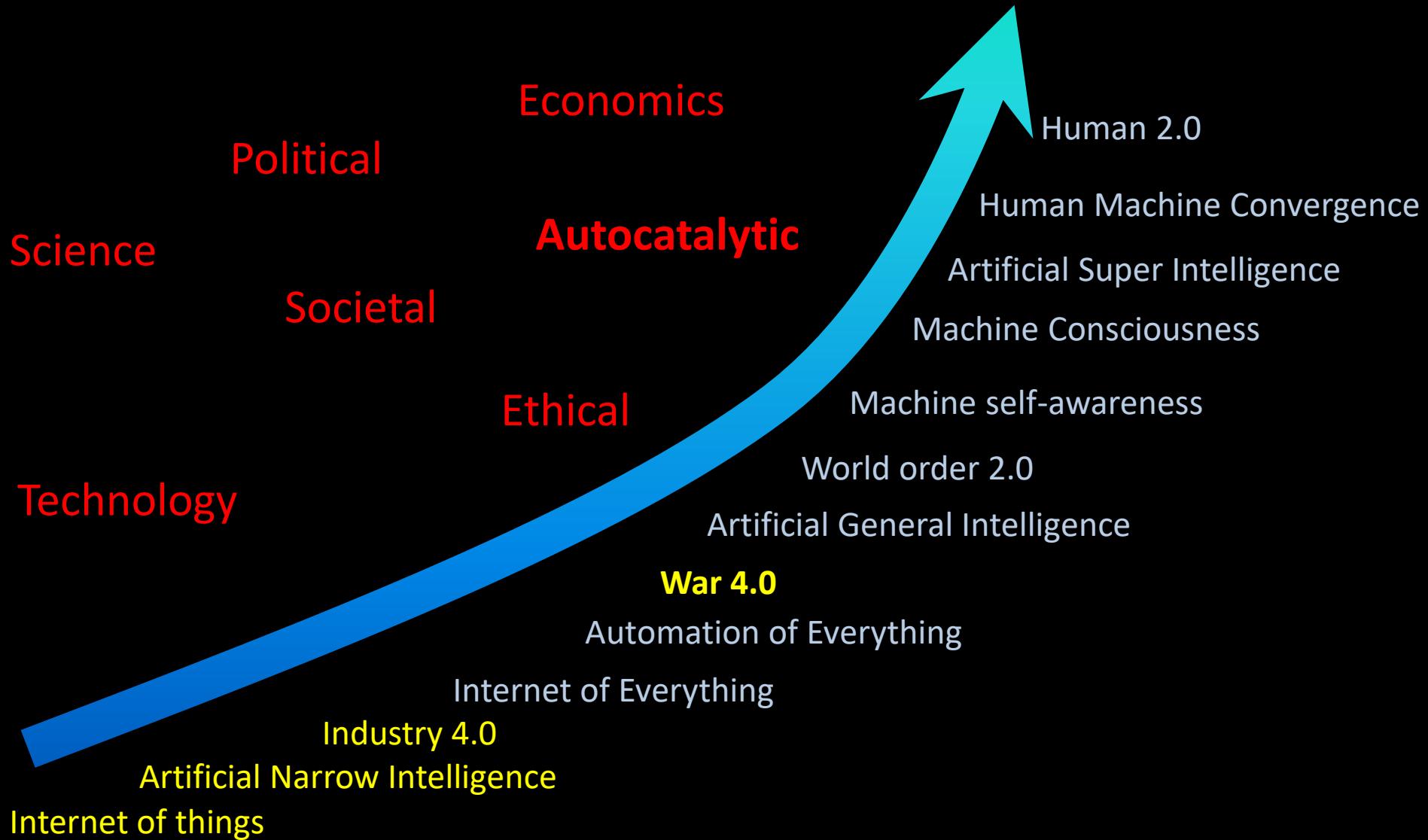
# The Future



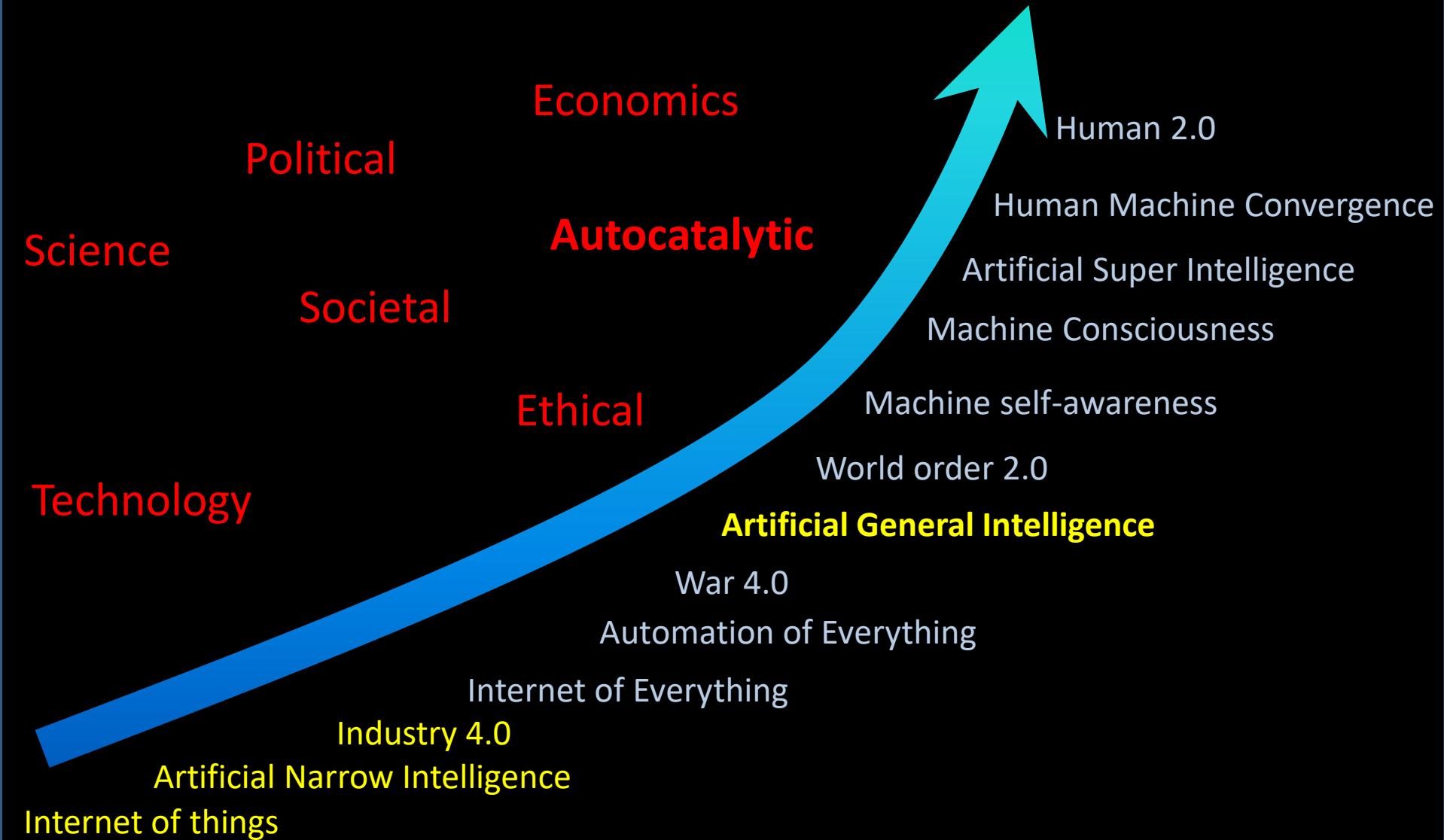
# The Future



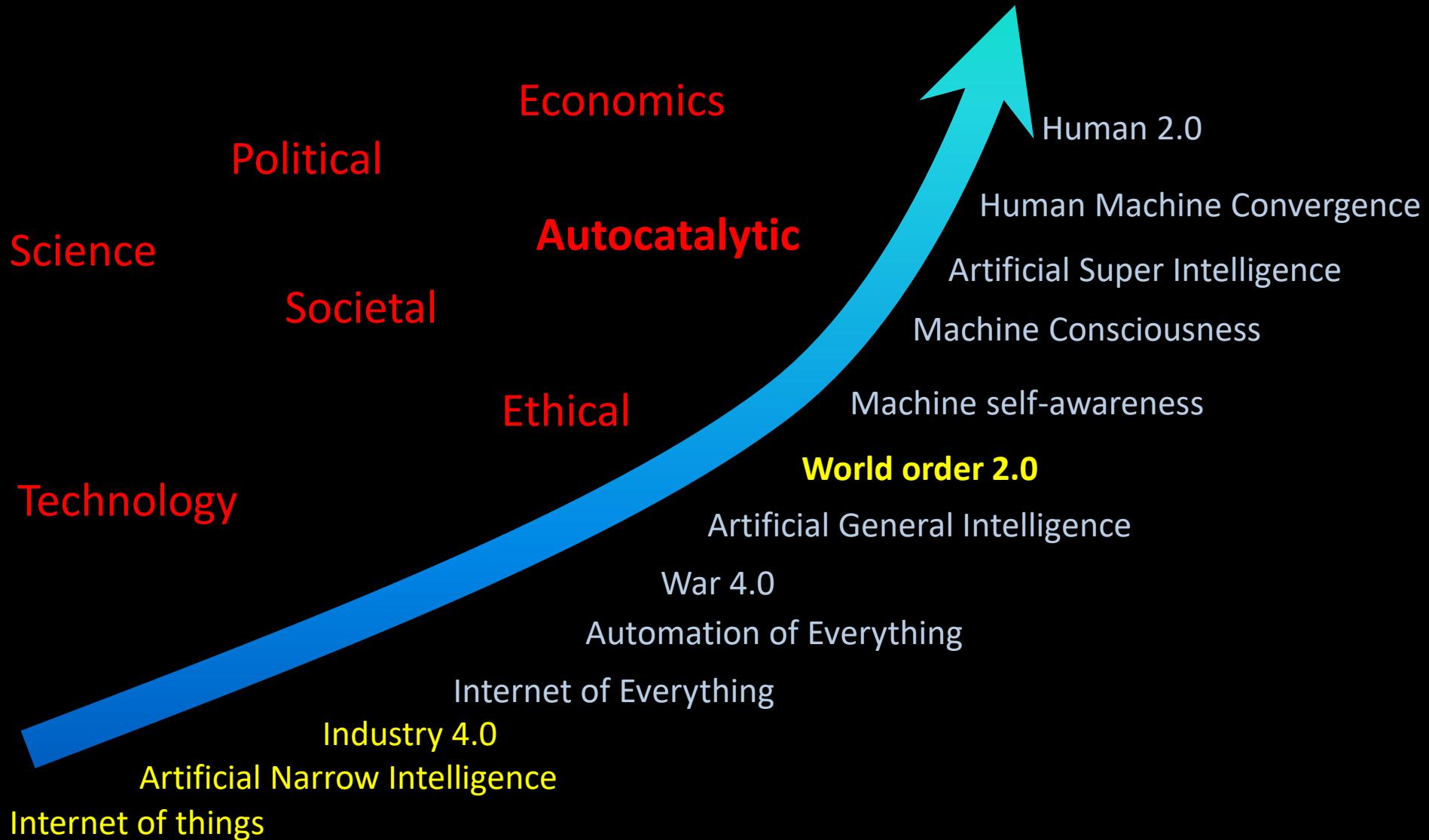
# The Future



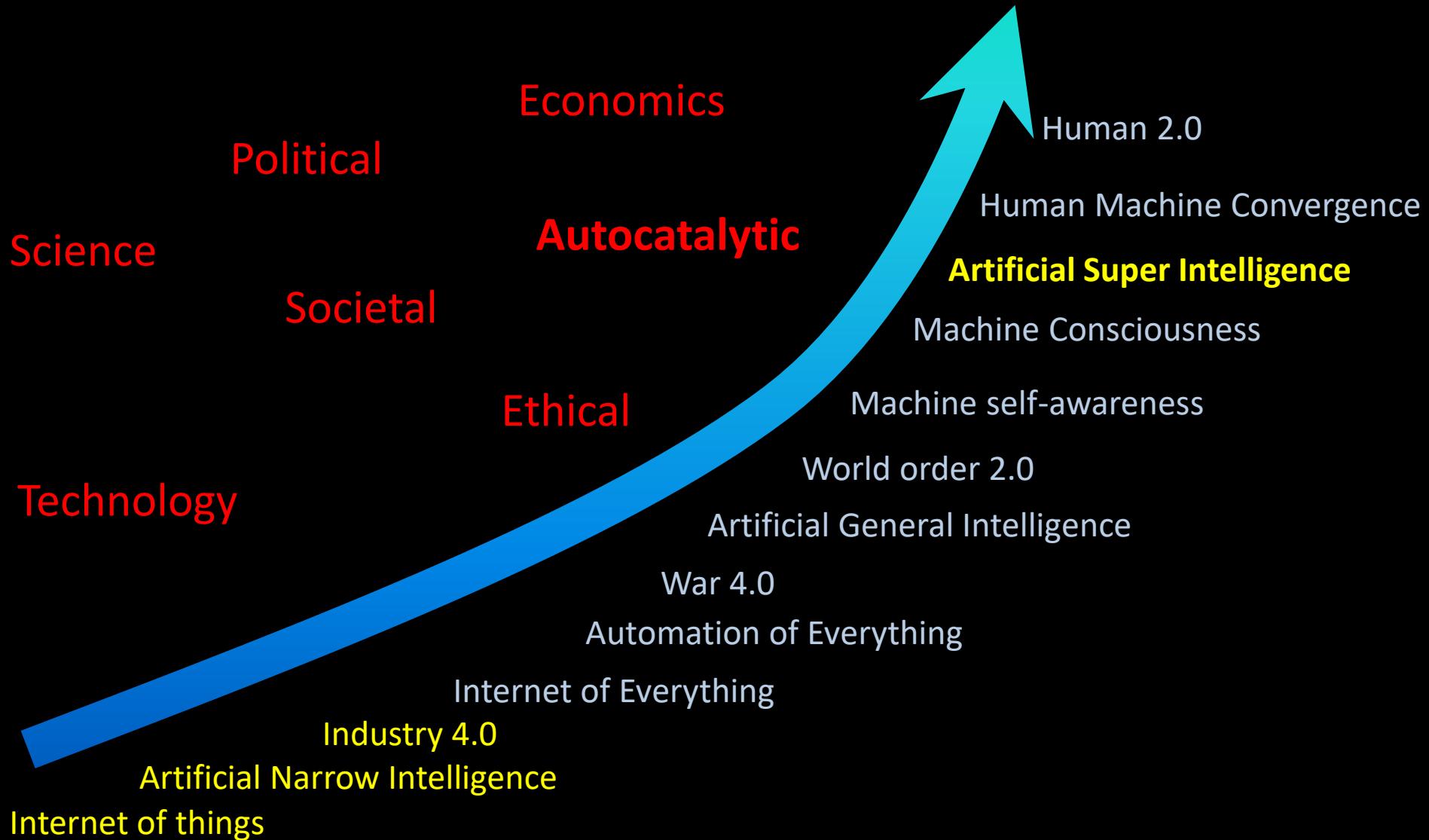
# The Future



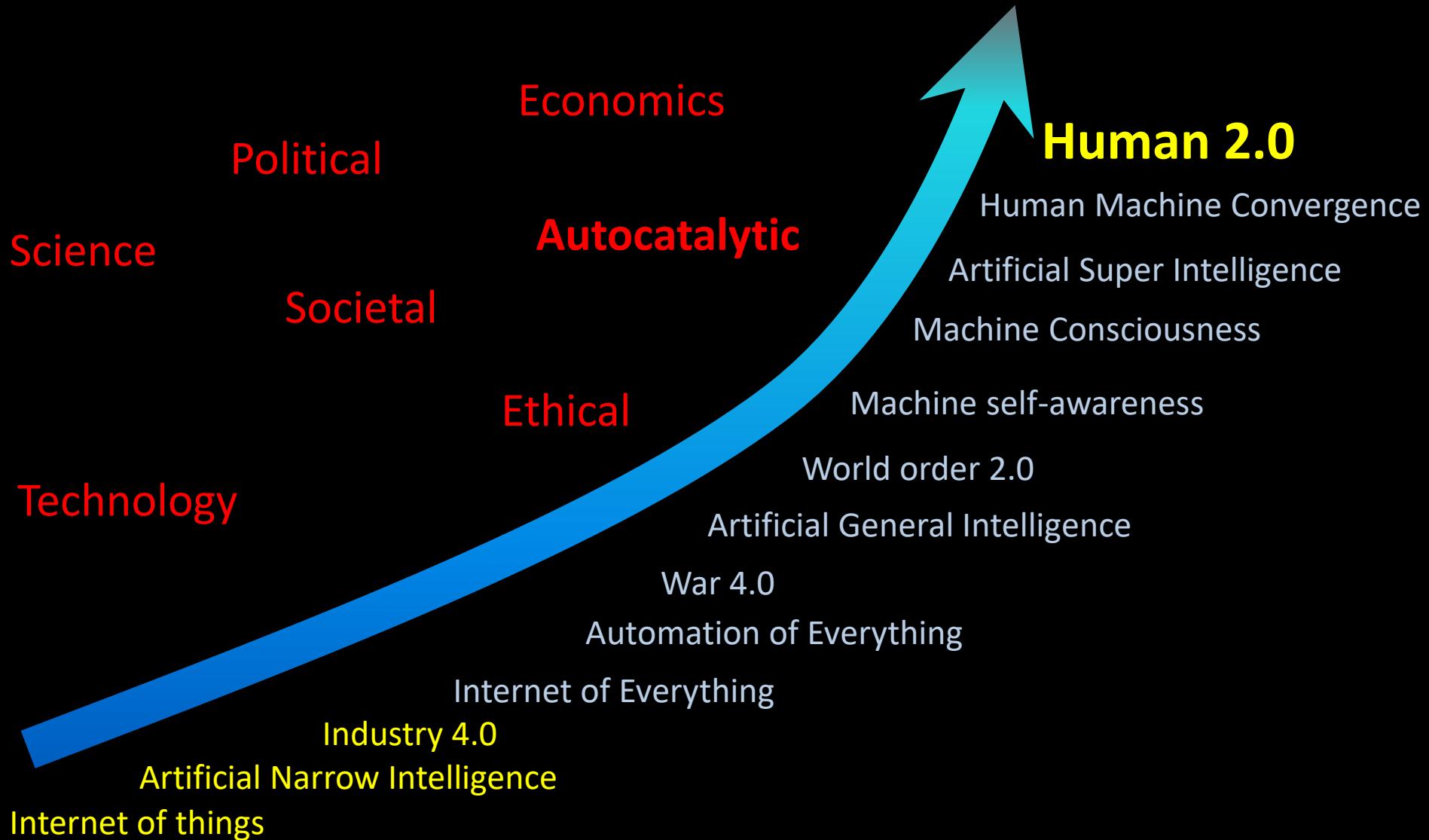
# The Future



# The Future



# The Future



# Concluding remarks

- The third wave of AI is inevitable
- **Data** would be the most critical resources
- We have to collectively and responsibly work to develop and harness this power

"Artificial intelligence is the future, not only for Russia but for all humankind... Whoever becomes the leader in this sphere will become the ruler of the world"

- Vladimir Putin

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