IEEE Computer Society 2022 Report

23 Computing Technologies That Will Shape the World in 2022

Dennis Frailey, *IEEE CS Board of Governors Member*
(Retired) Principal Fellow, Raytheon
Adjunct Professor, SMU and UTA

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Executive Summary

- 2012 – IEEE-CS Commissioned a Report on **technologies that will have major impact by 2022**
- 2013 – Report completed
  - 23 technologies identified
  - State of the art of each technology surveyed
  - Challenges identified
  - Where technology is going speculated
  - Potential disruptions identified
- 2014 – Factored the report into the 2014 update of the Computer Society's **strategic plan**

Presentation Outline

- Motivating Scenario – Seamless Intelligence
- Summaries of Some of the Technologies
- Survey of Drivers and Disruptors
- IEEE Computer Society in 2022

Report can be downloaded from:

www.computer.org/web/computingnow/2022-Report

Motivation and Goals

- Plan for the Future
  - Try to paint the state of the art of promising technologies
  - Identify potential disruptions and how they will evolve
- Contribute to society
  - How should IEEE CS fit in the new world of future
  - Directly feed into the Computer Society's strategic plans
- Envisioning the future is always a fun ☺
  - **And potentially risky ☹**

How

- Dejan Milojicic, then president-elect of the Computer Society, assembled a team of well respected technologists
- Team worked via a series of phone and F2F meetings
- Strengthened by surveys
- Input by volunteer leaders
- Final edits by staff

Two phases

1. Understand the Technologies
2. Propose how the IEEE CS organization should change in the future (publications, conferences, etc.)

Who – Core Team

- Hasan Alkhatib, (Entrepreneur, President SSN Services, LLC)
- Paolo Faraboschi, HP Labs, Spain
- Eitan Frachtenberg, FaceBook,
- Hironori Kasahara, Waseda University, Japan
- Danny Lange, Amazon
- Phil Laplante, Pennsylvania State University
- Arif Merchant, Google
- Karsten Schwan, GaTech
- Dejan Milojicic, HP Labs

Core Team Photos

Alkhatib

Faraboschi

Kasahara

Lange

Laplante

Merchant

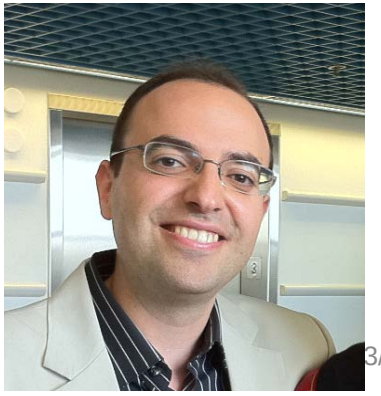
Schwan

Milojicic

Frachtenberg not shown

Additional Contributors

- Mohammed AlQuraishi, Harvard Medical School
- Angela Burgess, IEEE Computer Society, Executive Director
- Hiroyasu Iwata, Waseda University
- Rick McGeer, Communications and Design Group, SAP America
- John Walz, Retired from Lucent/AT&T





What: 23 Technologies in 2022

1. 3D Printing
2. Big Data and Analytics
3. Open Intellectual Property Movement
4. Massively Online Open Courses
5. Security Cross-Cutting Issues
6. Universal Memory
7. 3D Integrated Circuits
8. Photonics
9. Cloud Computing
10. Computational Biology and Bioinformatics
11. Device and Nano-technology
12. Sustainability
13. High Performance Computing
14. The Internet of Things
15. Life Sciences
16. Machine Learning and Intelligent Systems
17. Natural User Interfaces
18. Networking and Inter-connectivity
19. Quantum Computing
20. Multicore
21. Software Defined Networks
22. Robotics
23. Computer Vision & Pattern Recognition

Landscape (top level view) From Industrial Advisory Board

Market Category

- Life Sciences
- Computational Biology and Bioinformatics
- Medical Robotics

Technologies

- Computer Vision & Pattern Recognition
- Machine Learning & Intelligent Systems
- Natural User Interfaces
- 3D Printing
- Big Data and Analytics
- High-Performance Computing
- Cloud Computing
- Internet of Things
- Networking & Interconnectivity
- Software-Defined Networks
- 3D Integrated Circuits
- Multicore
- Photonics
- Universal Memory
- Quantum Computing
- Device and Nanotechnology

Human Capital

- Massively Online Open Courses

Policies

- Open Intellectual Property Movement
- Sustainability
- Security Cross-Cutting Issues

Seamless Intelligence Scenario

Technology Has Transformed the World

1940's 1950's 1960's 1970's 1980's 1990's 2000's 2010's 2020's

Increasing automation, ubiquitous access, pervasive networking

A revolution in the acquisition, manipulation and communication of information

Seamless Intelligence Scenario

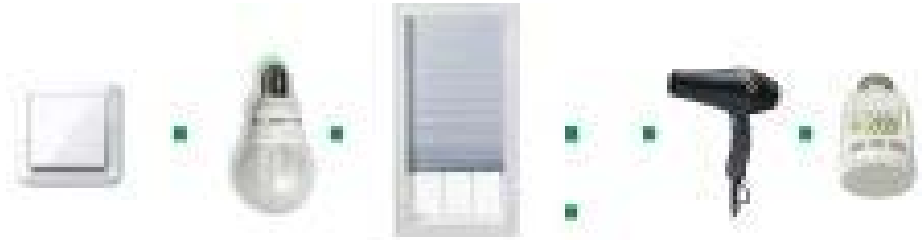
1940's 1950's 1960's 1970's 1980's 1990's 2000's 2010's 2020's

Increasing automation, ubiquitous access, perva

A revolution in the acquisition, ma
communication of infor

Intelligence becomes seamless and ubiquitous to those who can afford and use state-of-the-art IT

Seamless Mesh of Intelligent Devices



Seamless Networking

- At the heart is seamless networking
  - transition from one network device to another is transparent and uninterrupted
- Wireless, from NFC to Bluetooth, WiFi, 4G and 5G, integrated into high speed wired & Internet reach from anywhere to anywhere

Software Role

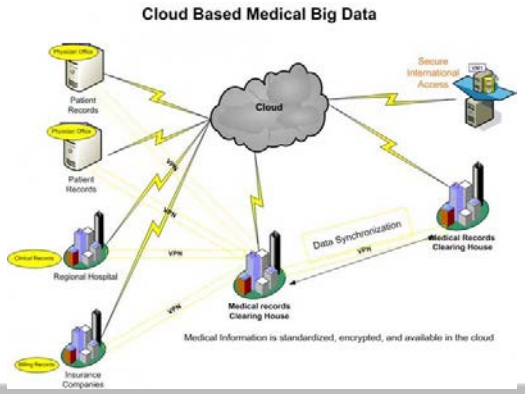
- Progress in **software-defined networking** is needed to achieve this seamlessness through ***virtualized end-to-end connectivity***
- This new world will require **sophisticated coordination software** to achieve integrated & complementary results among devices
- **Voice, image and motion recognition** will transform human-computer interaction (**HCI**) into ***seamless interaction between a person and all computing devices used in one's life***

Seamless Intelligence - Challenges

- **Federated identity**, and use of more sophisticated identity technologies and standards will need to be developed
- **Standard interfaces** are needed for mashing up a series of applications to achieve an ***integrated, collective, intelligent reality***
- Technology must provide powerful **voice and facial recognition**, massive identity databases, and powerful tracking
  - but ***controlling it will require collective social action***.

Seamless Intelligence, Sample Benefits

- Cashless and contactless financial transactions
- Ability to ***cross borders without stopping*** for inspection
- Walking into a bar in a foreign country and have the bartender offer you your favorite drink
- Healthcare: as one walks into a hospital, the ***entire medical history can be accessible*** to the attending medical professional from a centrally managed health vault



Seamless Intelligence: The Double Edged Sword

Seamless intelligence technology can be used …

to ***advance healthcare, education, science, trade, security and safety*** throughout the world, in all countries

OR

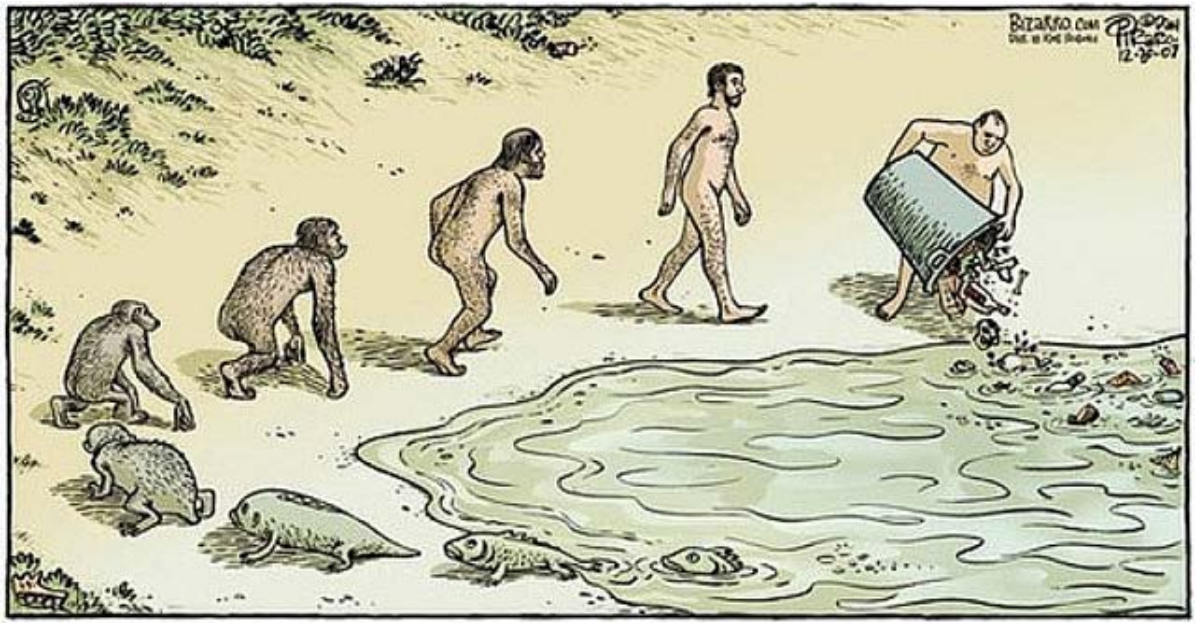
for ***militarization, invasion of privacy and Big Brother phenomena*** worldwide, even in countries that consider and pride themselves on being free societies

- **The future we want versus the future we don't want:** Information and communication technology is advancing at a pace that is ***surpassing our abilities in society to direct this progress based on public good***

How Can / Must Society Respond?

- **The scale and speed of this progress is the challenge**

There are choices that free nations can make through regulation and making choices in investment that can lead to a better world or a world that we do not desire



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Potential Disruptions - Examples

Development	Disruption
Mobile Smart Devices	The demise of traditional laptop and desktop computers for many applications
Computing as a Service (Cloud Computing)	Lessening role for traditional corporate and personal servers
Country / regional internets with restrictions on use	Limited ability of individuals to have access to truthful and complete information
Intellectual property battles	Delays in availability of technology

Topics To Be Discussed Here
(see the report for more topics and details)

Market Category

- Life Sciences
- Computational Biology and Bioinformatics
- Medical Robotics

Technologies

- Computer Vision & Pattern Recognition
- Machine Learning & Intelligent Systems
- Natural User Interfaces
- 3D Printing
- Big Data and Analytics
- High-Performance Computing
- Cloud Computing
- Internet of Things
- Networking & Interconnectivity
- Software-Defined Networks
- 3D Integrated Circuits
- Multicore
- Photonics
- Universal Memory
- Quantum Computing
- Device and Nanotechnology

Human Capital

- Massively Online Open Courses

Policies

- Open Intellectual Property Movement
- Sustainability
- Security Cross-Cutting Issues

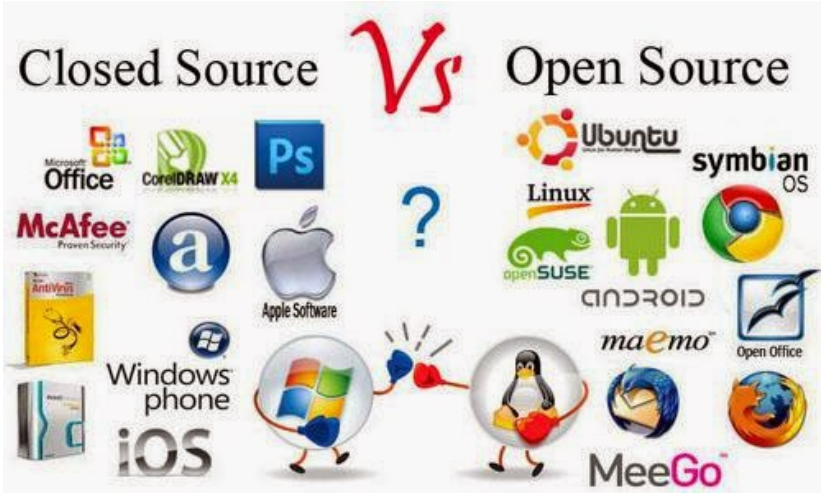
The Open Intellectual Property Movement

Open Intellectual Property - Potential

- ***Open source software, standards, open access publishing, and crowdsourcing*** are a positive byproduct of WWW ubiquity
- The open property concept is rapidly ***expanding into areas where property has traditionally been proprietary***, such as **hardware design**
- The growth of open intellectual property can potentially generate ***significant benefits to humankind***

Open Intellectual Property - Barriers

- Major challenges and risks include security and trust, ***motivation for innovators and diminishment of individuality***
- Existing legal concepts, especially regarding ***intellectual property***, may strongly impede open property
- The ***financial ramifications*** must be addressed by society



Massively Open Online Courses, MOOCs

Massively Open Online Courses

- Drawing ***hundreds or even thousands of students to a session***, MOOCs offer free or low-cost, high-quality, courses to anyone on the Internet
- They can be used for continuing education, credit bearing courses and even graduate education
  - Web-based course content, assessed through automated exams; assessment is optimized for ***automated grading***
  - Connective learning model via ***crowd-sourced interactions***; graduate assistants moderate interactions and answer questions
- Renowned scholars can reach immense audiences, ***underserved, remote populations***, with enormous societal impact

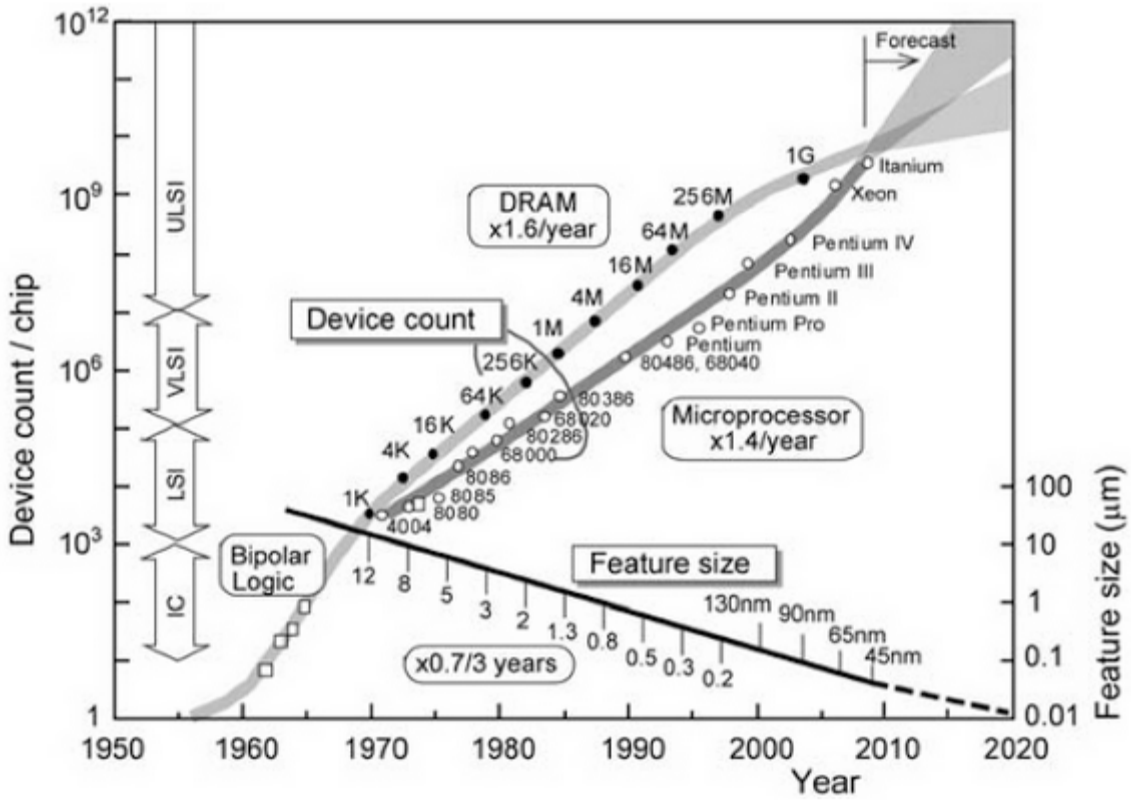
MOOC challenges

- Quality issues
  - Low completion rates (<8% of enrolled students)
  - ***Weak methods for protecting against plagiarism***
- Financial issues
  - It takes significant ***investment*** to build and maintain the MOOC platform
  - ***Compensation*** of educators

Universal Memory

Universal Memory – The End of DRAM is in Sight

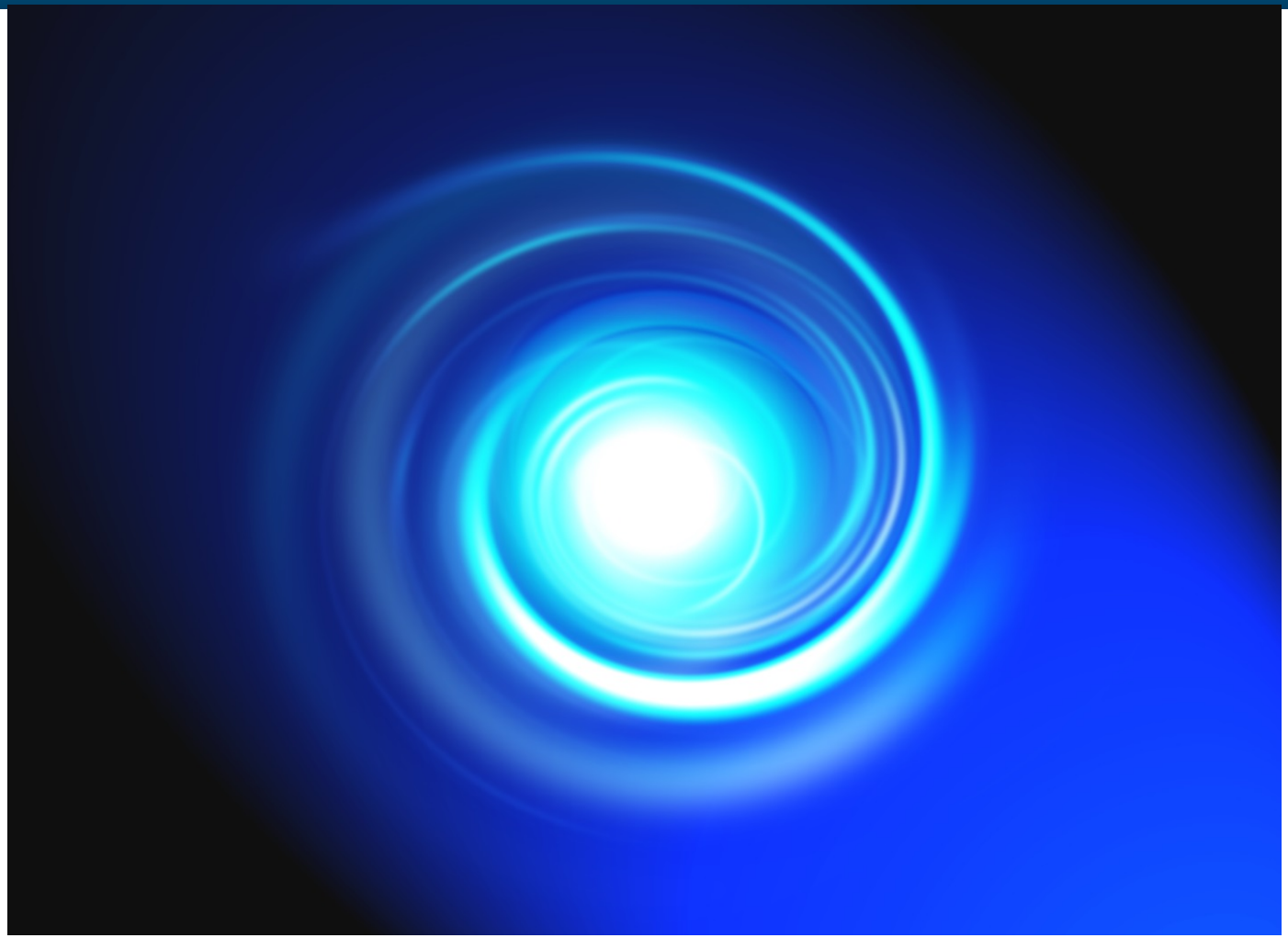
- DRAM has had a remarkable lifespan of over 40 years, with ***regular increases in scale*** of about 1.6x per year
- Because of the charge retention and manufacturability dictated by laws of physics, **the end of DRAM's scaling is in sight**



Universal Memory

- The next 5–7 years will see a significant shift for IT infrastructure, and we believe that ***memory will change profoundly***
- The ***number of memory manufacturers*** has been ***steadily decreasing***: 20 (85), 11 (95), 8 (07), 4 manufacturers today
- Between now and 2022, we expect that a new form of non-volatile "universal" memory NVM will replace DRAM
- It is difficult to predict exactly when and how, but transition is inevitable; ***there are signs of that happening, eg Flash***

Photonics

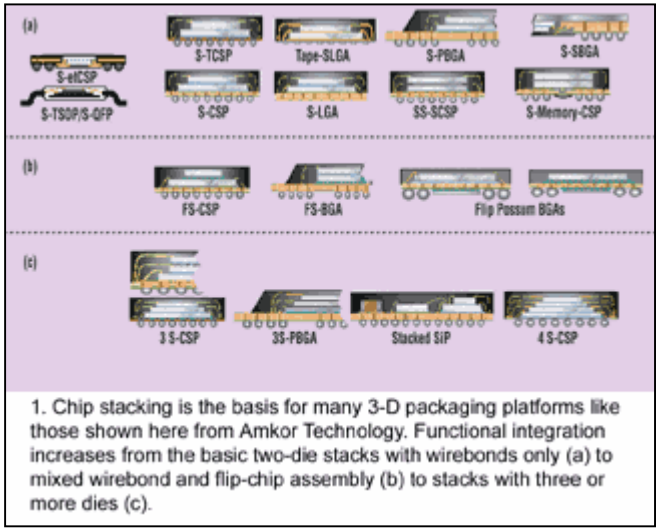


The Data Communication Challenges

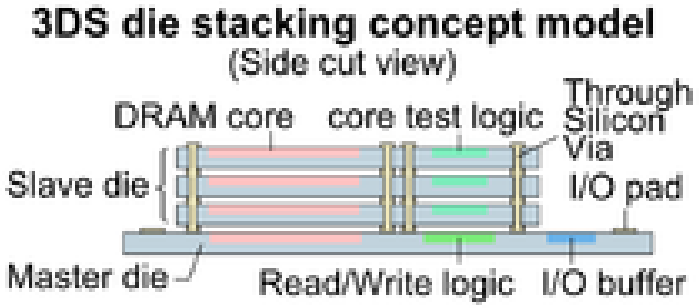
- There are 3 challenges in the roadmap for data communication:
  a) **energy efficiency,**
  b) ***scaling bandwidth,*** and
  c) delivering ***low latency across systems @ scale***
- Systems increasingly require wider bandwidths, but ***communication energy grows nonlinearly with bandwidth***
- Today ***the energy to move data exceeds the energy to compute on data***
  - and this trend will continue

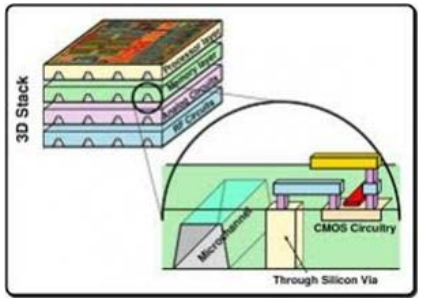
3D Integrated Circuits

- Today, we are making great strides in building three dimensional integrated circuits.
- At the processor-memory level, tighter integration using 3D-ICs technologies will address several communication challenges



1. Chip stacking is the basis for many 3-D packaging platforms like those shown here from Amkor Technology. Functional integration increases from the basic two-die stacks with wirebonds only (a) to mixed wirebond and flip-chip assembly (b) to stacks with three or more dies (c).

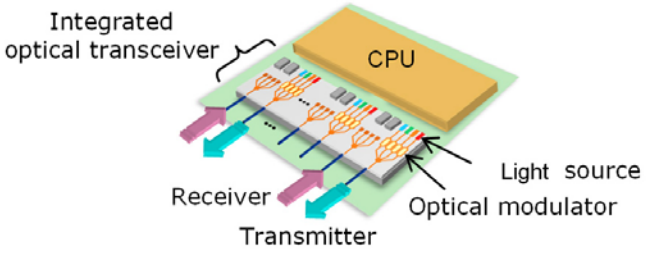


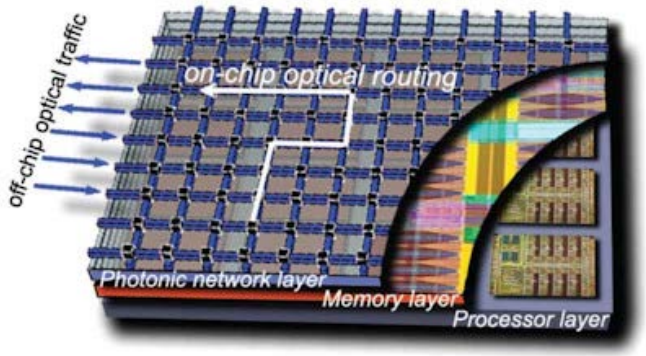


Photonics – The Potential Solution

Photonics: the science and technology of generating, controlling and detecting photons (light particles)

- Emerging silicon photonics offer lower power, high bandwidth, and overcome ***link length restriction of electrical interconnect***
- Silicon photonics is foundational for high-end systems: in 2022, it is ***the only technology that can reach Exascale objective***





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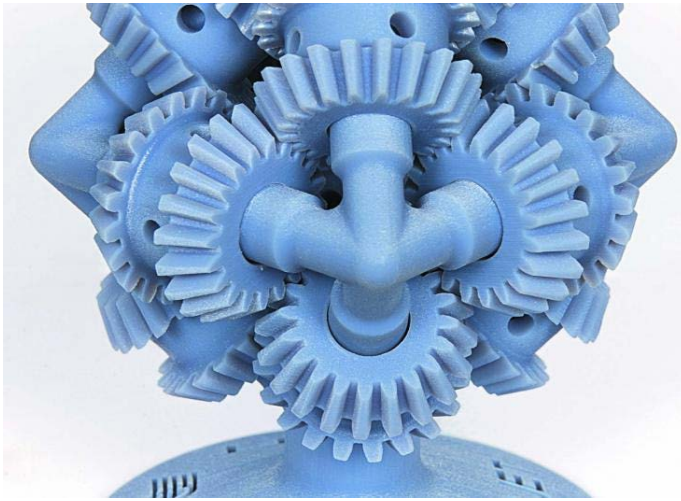
3D Printing - Today

3D printers already ***create many shapes using combinations of materials***

- Many are difficult to create with conventional methods



- They handle products from inches to feet; materials from plastic to metal, to foods, to stem cells to create living tissue

3D Printing – Medical Applications

- ***Custom prosthetics*** and even replacements for body parts may be 3D printed
  - e.g. cartilage formed from printed molds
- Combining different materials allows creation of ***composite materials with new properties***
  - e.g. ability to self-heal after failure

3D Printing – Tomorrow

- Printing batteries and sensors on objects will enable those objects to sense the surrounding temperature, light, and even impending failure
- Printing **complete, fully functioning devices** (electronic and mechanical) will ***make redundant*** the process of ***assembling them*** from parts
- Manufacture of many products will move ***from large, centralized factories*** to ***local workshops and even homes***

Big Data and Analytics

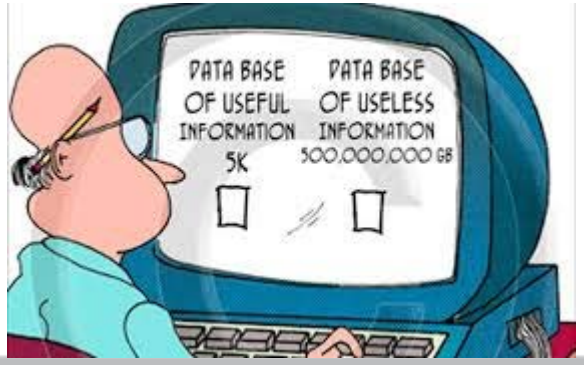
Today We Produce a Lot of Data

- Data is collected, shared, and analyzed every day
  - great potential to ***improve data-driven decisions***
- Worldwide, we can now produce around **15 petabytes** of compressed genetic data per year
  - this is ***growing at a rate of 3-5x*** per year
- In high-energy physics, the Large Hadron Collider and other instruments in CERN alone produce a similar amount of data

The challenge: analyzing all that data.

Big Data and Analytics

- These techniques can potentially have tremendous impact in ***reducing uncertainty around decisions, before they're made***
  - ➢ and afterwards too
- But there are significant ***technological/societal challenges***:
  - rapid changes in: acquisition, storage, and processing
  - education of workforce/everyday users
  - **complex privacy issues**



Robotics in Medicine

Robotics in Medicine - Today

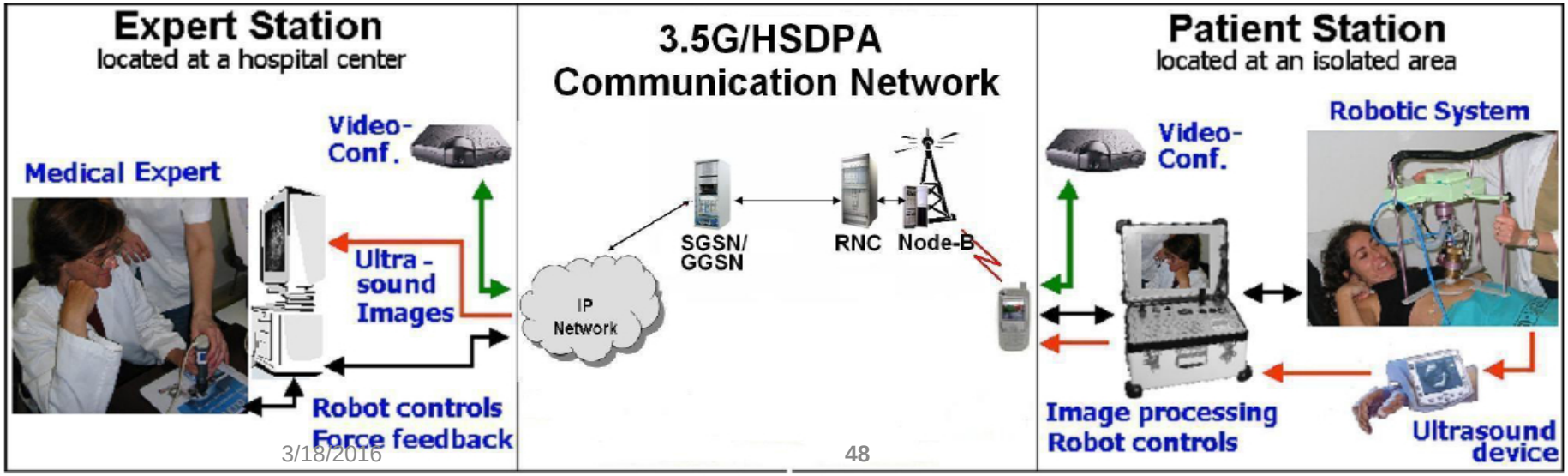
- Computer science helped evolve invasive image processing and measurement techniques to ***screen undiscovered diseases***
  - 3D Hi-vision endoscope, navigation system and surgical robotic system
- ***Computer Aided Surgery*** is expected to become standard operation due to its low invasiveness, lower hand vibration and highly accurate positioning
  - ***Reducing physical burdens on patient***

Da Vinci Surgical System

- More than 2700 installations
  - But the ***distribution and surgical applications are still limited***

Robotics in Medicine - Future

- Robotics will have a great potential to allow patients, elderly, and pregnant to undertake ***Tele-[checkup, diagnosis, therapy]***
  - ➢ beyond hospital, region, country, and even continent
- Tele-echography robot, will be applicable to ***critical care in long-travel ships and aircraft***



Security Cross-Cutting Issues

Security Cross-Cutting Issues

- We face a ***tradeoff between privacy, security, and convenience***.
  - Changes in laws & improvements in privacy-enhancement tools and techniques may be needed to ***find a balance*** between **tolerable levels of intrusion** and **desired levels of security**
- Powerful forces are converging that are of great concern to individuals and to public entities.
  - exponential growth of **large data repositories**;
  - enhanced ***capability to analyze*** data for various patterns;
  - advancing ***ability to collect diverse data***
  - ***adversarial*** government agents, criminals, and enemies.

Survey of IEEE Members

Conducted as part of the 2022 study

Survey

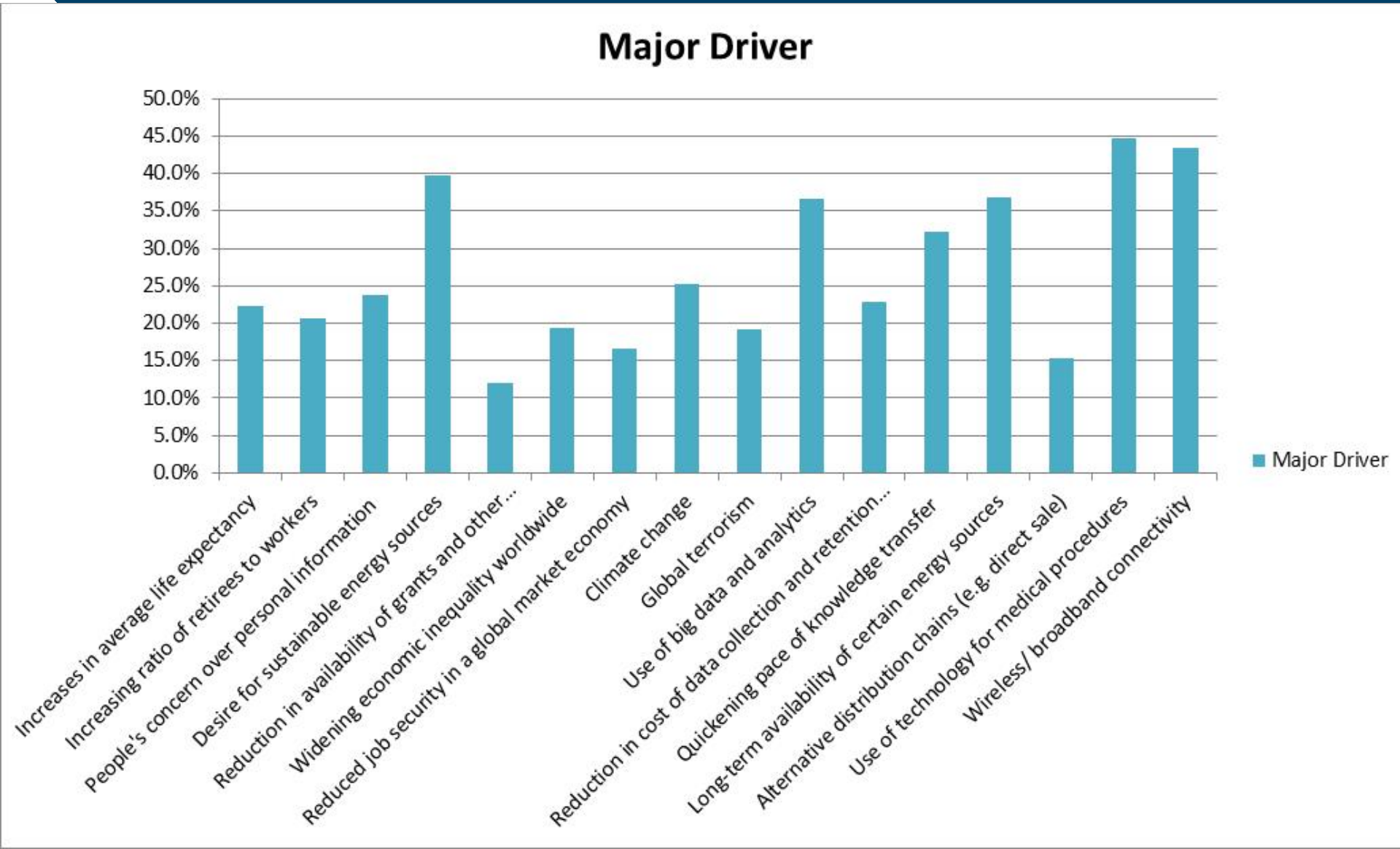
- Several Thousand IEEE Members were Surveyed
- Two classes of questions:
  - What are the major driver technologies?
  - What are the major disruptor technologies?
- Result:
  - Overall rankings of drivers and disruptors

Respondents were asked to rank these

Survey Outcome: Drivers

- Increases in average life expectancy
- Increasing ratio of retirees to workers
- People's concern over control over access/amount of personal information
- **Desire for sustainable energy sources**
- Reduction in availability of grants and philanthropic resources
- Widening economic inequality worldwide
- Reduced job security in a global market economy
- Climate change
- Global terrorism
- Use of big data and analytics
- Reduction in cost of data collection and retention (for use in analytics)
- Quickening pace of knowledge transfer (e.g. instantaneous global communication)
- Long-term availability of certain energy sources
- Alternative distribution chains (such as manufacturers selling directly to consumers)
- **Use of technology for medical procedures**
- **Wireless/ broadband connectivity**

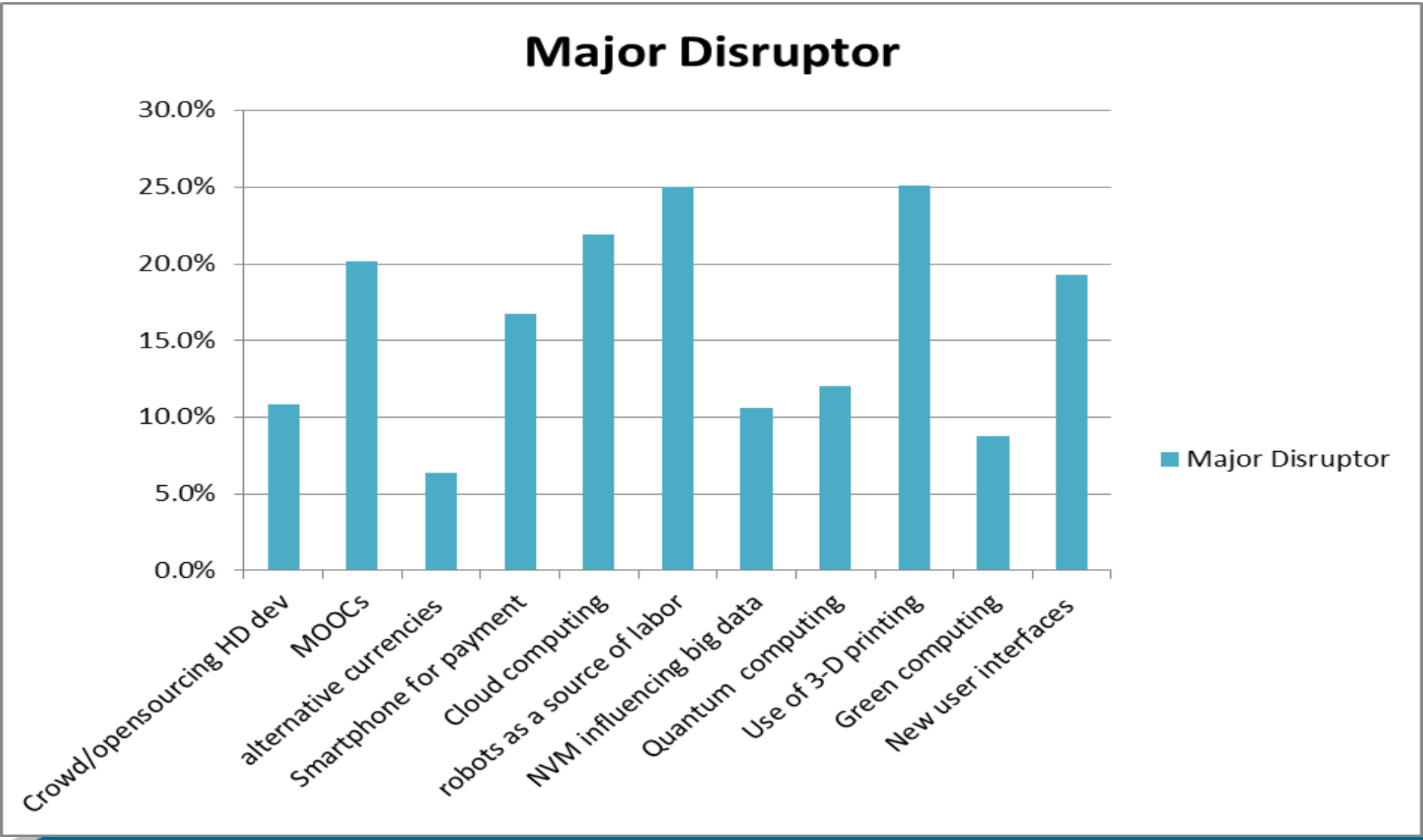
Survey Outcome: Major Drivers



Disruptors

- Crowdsourcing / opensourcing of hardware development
- Changes in educational structure/design, eg, Massive Online Open Courses
- Virtual/alternative currencies (such as bitcoin)
- Smartphone use as a device for payment
- **Cloud computing**
- **The growing use of robots as a source of labor**
- Non-volatile memory influencing accessibility and portability of big data
- Quantum/non-deterministic computing
- **Use of 3-D printing**
- Green computing
- New user interfaces.
  - eg, Siri, Kinect instead traditional keyboard/mouse interface

Major Disruptors

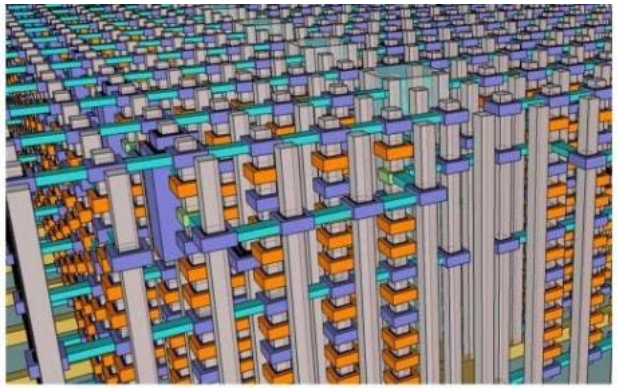


IEEE Computer Society in 2022

- Society for professionals'/students' seamless intelligence
  - Membership that is **on average 10 years younger**
  - **Cool factor**, but maintain traditional engineering principles rigor
  - T**ruly global** and truly connected
- New products
  - **Instant access, publish, collaborate**, meet physically/virtually
  - **New standards**: living code, practices, building codes
  - **Learning by doing** and from doers
- Societally mindful of **preserving privacy**
  - At pace with technology, but not faster than societal changes
  - Know only as much about a member as he/she allows

2022 Report Conclusions (1 of 2)

- By 2022, **computing devices will vary from nano- to mega-scale**



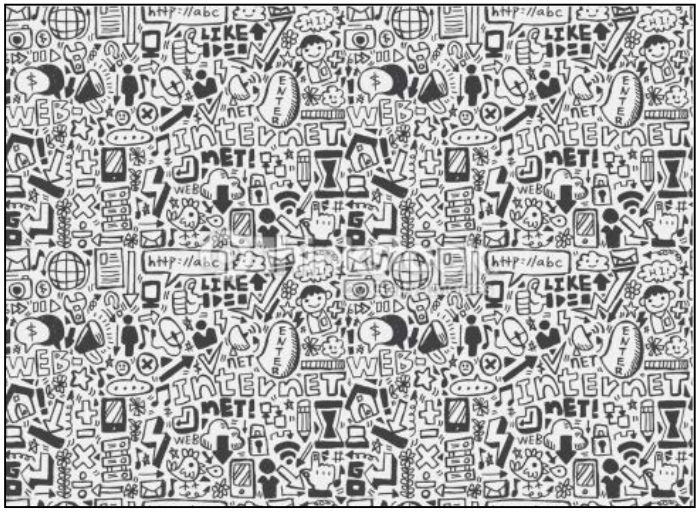
3-D Integrated Nanowire Fabric Vision

Microsoft mega scale data center, Dublin, Ireland (opened 2009)

- Wireless/wired networks will enable access to world-wide integrated services
- Virtual connectivity will enable integration of relevant computing resources to provide users with **integrated and seamless services**

2022 Report Conclusions (2 of 2)

The resulting ecosystem will offer seamless, continuous, uninterrupted services that enhance automation, productivity, collaboration and access to intelligence and knowledge



The benefit of technology is what we make of it: societies will face challenges in technologies that benefit humanity instead of destroying and intruding on human rights of privacy and freedom

Thank you!

Questions