Technology Megatrends Discussion with SSL Annex Experts in Stockholm

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2023

Technology Predictions

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Introduction

Technology Predictions: from Hypothetical Exercise to Critical Planning

- COVID-19 pandemic impact[1]
  - As of Dec 28th, 2022, 663,666,629 affected (6,692,552 deaths) (https://www.worldometers.info/coronavirus/).
  - The GDP downturn in 2020 and 2021 (estimated 3-5%) has seen in 2022 a recovery to 2019 levels in the 40 more developed Countries. Less developed Countries and poor ones are still affected.
- Pandemic had impact on human lives, supply chains, work, unpredictability of operations and markets.
- Counter-measures: cutting costs, repurposing assets, eliminating middle-men, shift to “as-a-Service” models.
- Pandemic has created stress on our daily lives and values
  - Social distancing limited opportunities for social interaction.
  - Future of work: many in-person workplaces and classrooms transitioned to virtual.
  - AI was entrusted to assist in transportation, healthcare, eldercare, etc.
- Acceleration of the Digital Transformation was forced upon work, education, and private life.
- Technologies play increasingly crucial role and are becoming essential.
- Predictions go beyond a hypothetical exercise to encourage technologies to address pandemic concerns.

[1] https://www.statista.com/topics/6139/covid-19-impact-on-the-global-economy/


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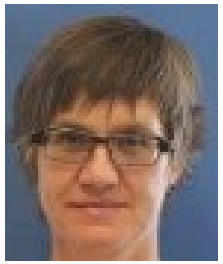
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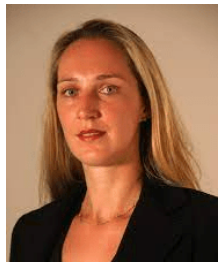
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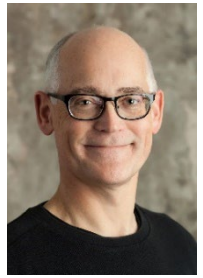
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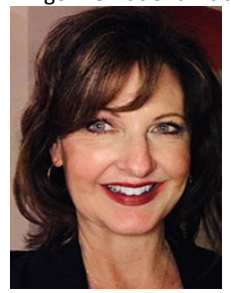
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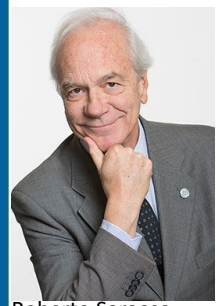
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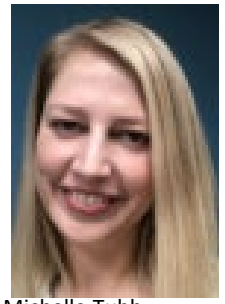
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2023 Technology Predictions Team

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Process: continued improvements over previous years

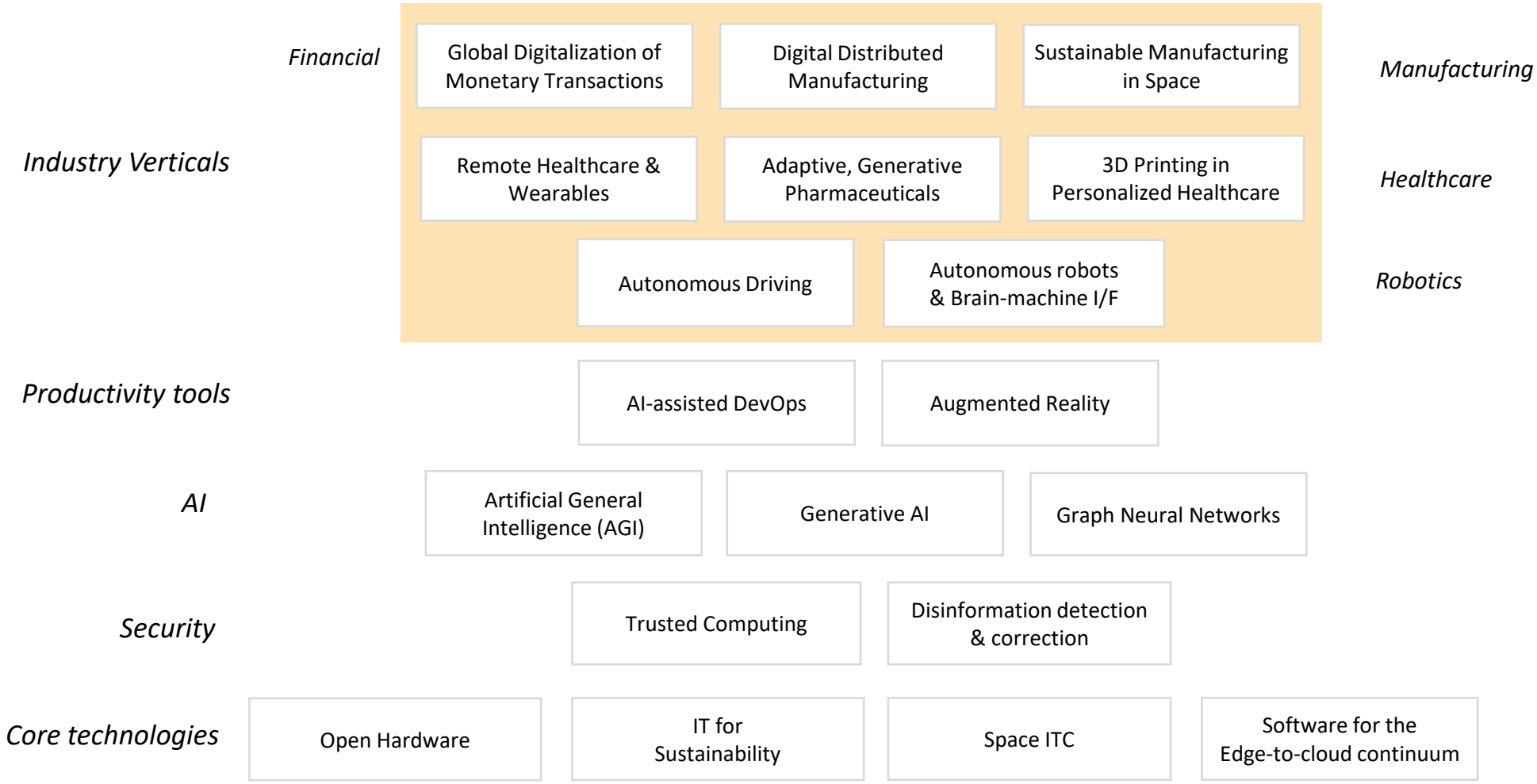
- Selection
  - This year we expanded our team from 16 (2022) and 12 (2021) to 35 members, adding perspectives from Middle East, Australia and further expanding insights from Africa, Asia, Europe, and Latin America.
  - We also further improved our diversity both in terms of authors and the covered areas.
  - Authors made one or more predictions, resulting in 59 predictions; we merged several, leaving us with 30 that we voted upon.
  - We then down-selected to 20, by each author giving one of 16 votes to one technology.
  - We then did another careful merging of some proposals and ended up with 19.
- Grading: In the second round we graded each technology
  - (A-F) for: a) Predicted Technology Success in 2023; b) (Potential for) Impact to Humanity; c) Predicted Maturity in 2023; d) Predicted Market Adoption in 2023.
  - (1 year, 3y, 5y, 10y, 15y) for Horizon to Commercial Adoption.
  - Intent was to present impact to humanity as a function of technology advancement, also qualifying those by relative maturity, market adoption and positioning in time-to-adoption.
  - We also calculated a) our confidence as standard deviation in voting; and b) bias as a correlation between individual grades.
  - Finally, we did final tweaking and optimizing until the last moment, with the end customer (you the reader ☺) on our mind as a priority.
- Qualifying
  - For each of the 19 technologies, the proposer(s) wrote a slide discussing: problems/demand, opportunities, impact, and sustainable solution/business opportunity.
  - For each technology, we primarily focused on its computer science aspects.

Predictions*

1. **Remote Healthcare & Wearables** (B+): Remote healthcare with advanced wearables will enable patients to obtain remote medical assistance, physicians to perform procedures and consult with remote experts, and both to have access to vital health information.
2. **Augmented Reality** (B): Seamless integration between the real world and cyberspace will increasingly materialize.
3. **Software for edge2cloud continuum** (B): *New software for the development and deployment of next-generation computing components, systems, and platforms that enable a transition to a compute continuum with strong capacities at the edge and far edge in an energy-efficient and trustworthy manner.*
4. **Open Hardware** (B): From open systems (OCP) to ISAs (RISC-V) and interconnects (CXL, UCIe) the open-source movement has expanded into hardware.
5. **AI-assisted DevOps** (B): The traditional DevOps approach will be improved to address the increasing complexity of software systems.
6. **3D Printing in Personalized Healthcare** (B-): 3D printing in healthcare will evolve toward customized additive manufacturing for individuals.
7. **Generative AI** (B-):*In the next few years, generative AI will be used even more, increasing effectiveness and enabling new services. It is also bound to raise ethical and societal issues. Expect strong impact on business (short term), on education (long term) and on society (medium to long term).*
8. **IT for Sustainability** (B-): Technology will evolve from sustainable IT to novel uses of IT for sustainability, clean energy, and a green economy.
9. **Autonomous Driving** (B/C): Self-driving vehicles in controlled environments are starting to gain adoption at scale, backed by strong business cases.
10. **Digital Distributed Manufacturing** (B/C): Digital Distributed Manufacturing will reduce the energy and environmental footprint and increase the resilience of supply chains.
11. **Trusted Computing** (B/C): There will be increased public awareness and attention to trusted/assured computation across all industry sectors. Governments will increase focus on legislative actions to ensure that public facing systems can be trusted.
12. **Huge Graph Neural Networks** (B/C): *Applications that use huge models, such as chatGPT, have demonstrated a real impact on a substantial set of problems. Graph Neural Networks can represent complex, "real-world" structures. We predict that huge GNN models will widely be used in machine learning.*
13. **Adaptive, Generative Pharmaceuticals** (C+): Advances in nanotechnology and AI could shorten the time to vaccine development and broaden their efficacy.
14. **Autonomous robots & Brain-machine I/F** (C+): Pervasive uptake of robotic platforms will take place, including as extensions of the human body.
15. **Artificial General Intelligence (AGI)** (C+): Advances in AI will lead to AGI systems that can understand or learn any intellectual task that a human being can perform.
16. **Global Digitalization of Monetary Transactions** (C+): Digital transformation of monetary transactions will open new disruptive opportunities in global markets.
17. **Space ITC** (C): As more companies send technology to space, the barriers to entry are decreasing rapidly.
18. **Sustainable Space Manufacturing** (C/D): Space manufacturing and recycling technologies and services will improve sustainability, resilience and cost of the space ecosystem.
19. **Disinformation detection/correction** (C/D): Improving the reliability of information in public health, politics, and science will improve public information required for sound decisions from personal to societal levels.

*sorted by likelihood of success

Predicted Technologies



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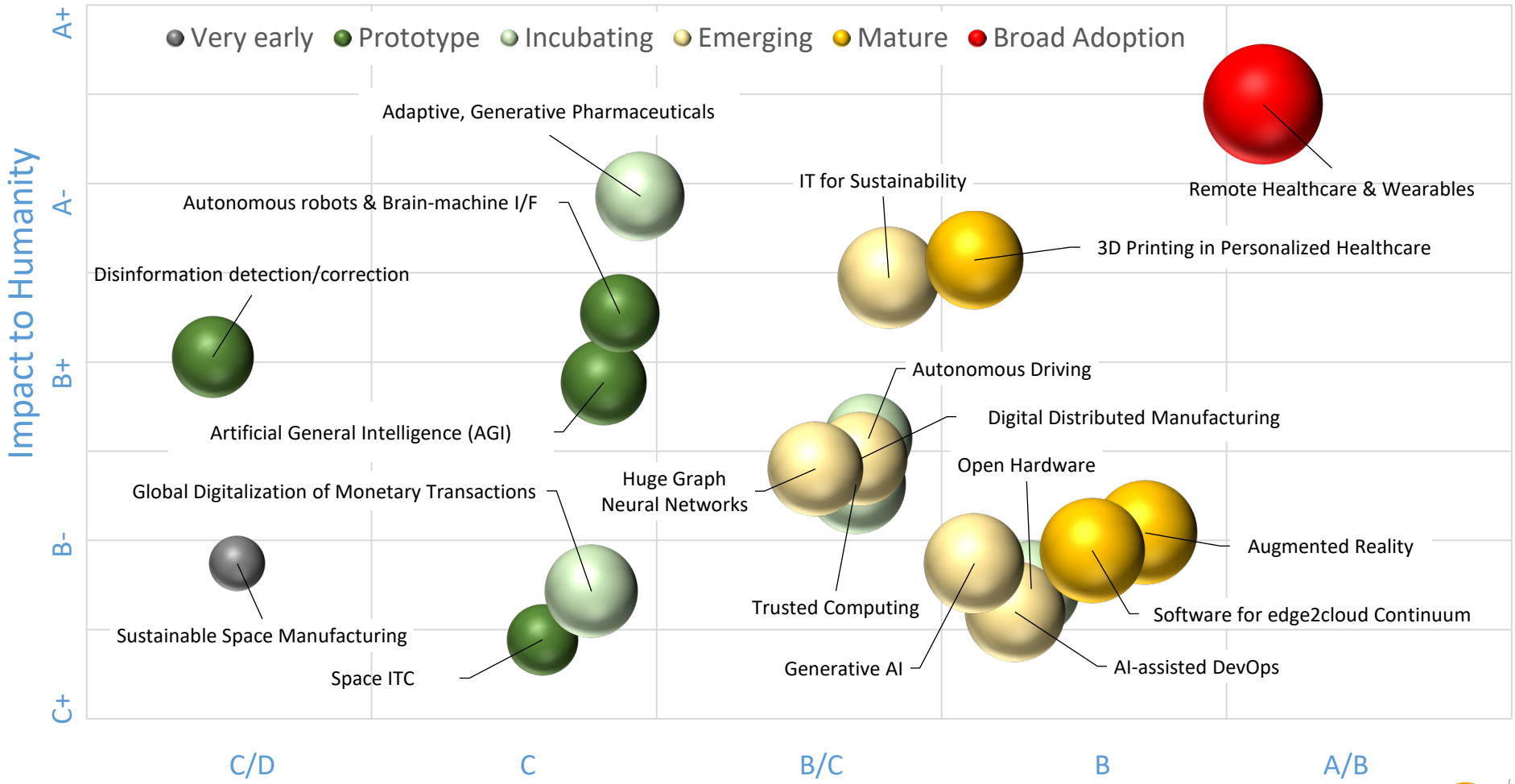
Comparing 2023 Technology Predictions, Four Ways

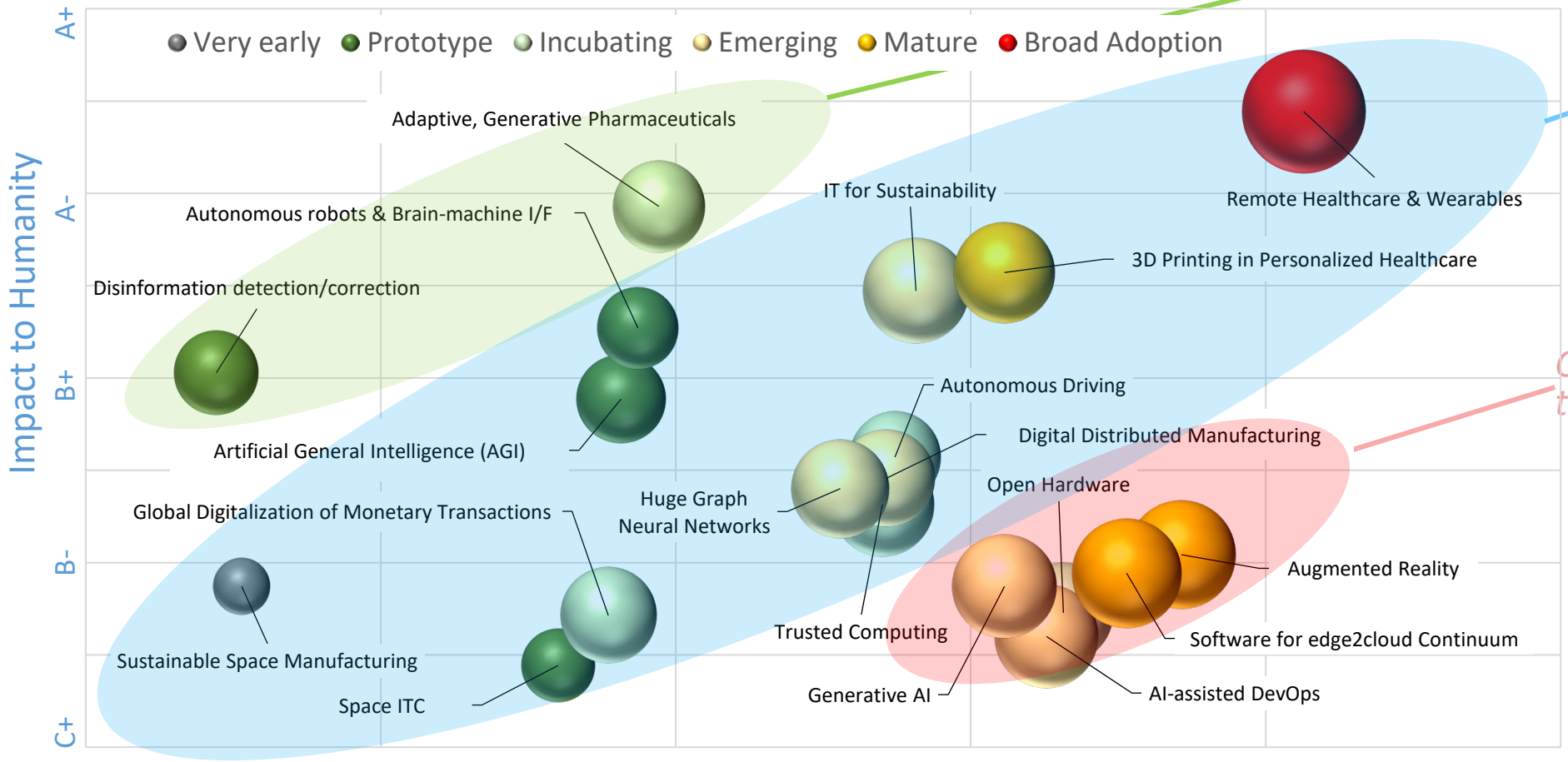
Technology Success (x-axis) vs Impact to Humanity (y-axis)
(size of bubble proportional to relative market adoption)



Comparing 2023 Technology Predictions, Clusters

Technology Success (x-axis) vs Impact to Humanity (y-axis)
(size of bubble proportional to relative market adoption)

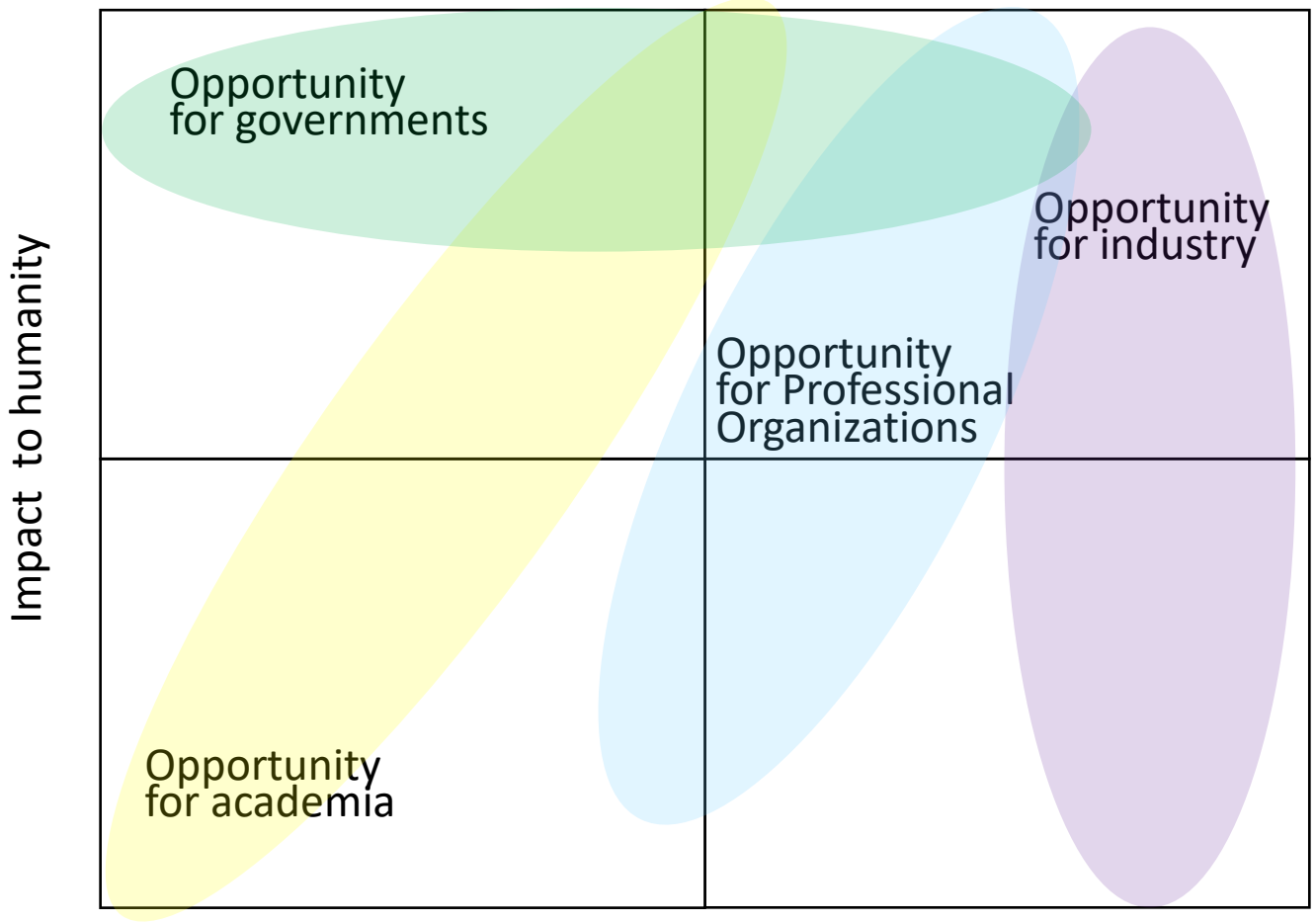
Impact on humanity higher than chance of tech success ***(worth investing in)***



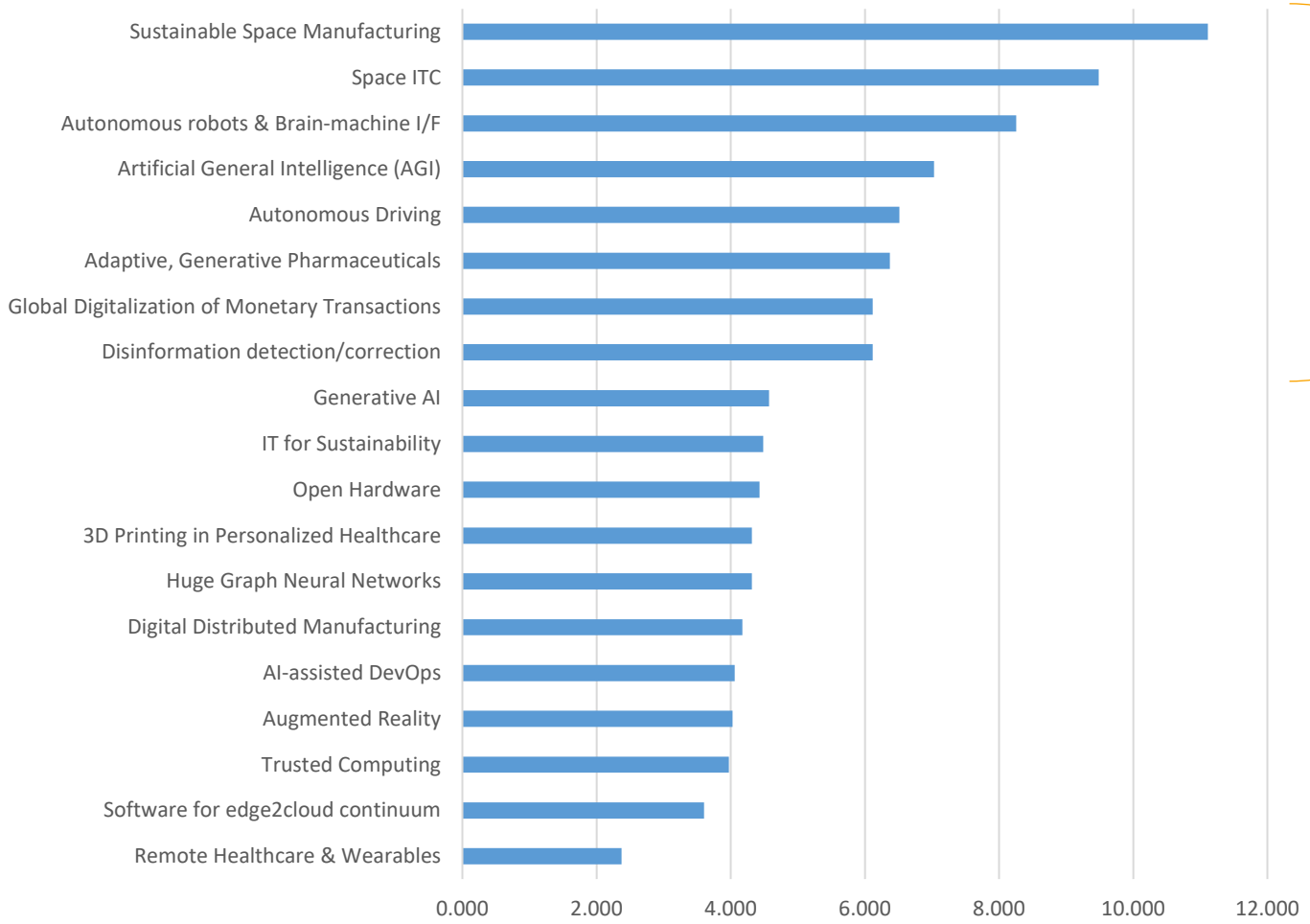
Chance of success correlates to impact on humanity

Chance of tech success higher than impact on humanity

How to Use Results, Technology-to-Humanity Quadrants



How to Use Results, Horizons to Commercial Adoption



Opportunity for academia (out-of-box thinking, innovations)

Opportunity for governments (funding, regulations)

Opportunity for professional organizations (standards, future directions, roadmaps)

Opportunity for industry (inventions, productization, new markets)

Insights and Opportunities

- Clear predicted success is Remote Healthcare & Wearables (in terms of technology advance **and** impact to humanity).
- Business opportunity are cluster of technologies which will likely succeed (augmented reality, software for edge to Cloud, etc.)
- Concern are technologies with large impact to humanity but less chances for technological success (disinformation detection, adaptive generative pharmaceuticals).
- Long-term opportunity are space technologies and global monetization.
- "AI will eat the world" (Mark Andreessen paraphrase). Almost all of the technologies benefit from or crucially rely on advances in AI.
  - Without AI, there's much less (in these areas).
  - We're also predicting advances in AI proper, which feeds back into the loop, accelerating all the other technologies.
  - This suggests that nearly all the slides could have an enabler and inhibitor in the form of "advances in AI".
- Fear, Uncertainty and Doubt (FUD, all forms of mistrust).
  - The world is unfortunately ruled by FUD.
  - FUD can be countered by technologies–directly (trusted computing, disinformation), or indirectly (AI-related, Openness).
- Opportunities for industry
  - Health industry (remote, wearables, custom 3D printing)
  - Augmented reality
  - IT for sustainability
  - Open hardware
- Opportunities for governments
  - Regulate: Disinformation detection, generative pharmaceuticals
  - Fund: Space technologies
- Opportunities for academia
  - Space technologies (ITC, manufacturing, recycling)
- Opportunities for professional organizations
  - AI-related, Sustainability, Space

Summary

- Outlook
  - Technologies will continue to be critical in addressing and preventing pandemics, wars, and natural disasters.
- Predictions
  - We made nineteen predictions in four areas (core technologies, security, AI, productivity tools) and four industry verticals (healthcare, robotics, manufacturing, and financial).
  - We graded our predictions in terms of likelihood technology success, impact to humanity, maturity in 2023, market adoption in 2023, and horizon to commercial adoption.
  - Predicted technologies show a degree of correlation, but with more diverse roster we got less correlation this year.
- Future work
  - We continue to eliminate bias, as demonstrated by correlation and standard deviation.
  - We are exploring collaboration with market analysts to include the total addressable markets of technologies.
  - In the future, we plan to devise recommendations to industry as a function of our predictions.
  - At the end of the year, we will prepare a scorecard on how technologies succeeded against our predictions.

1. Remote Healthcare & Wearables

Remote healthcare and advanced wearables will enable patients to obtain remote medical assistance, physicians to perform procedures and consult with remote experts, and both to have access to vital health information.

Problems/Demand

- COVID-19 made remote medicine more attractive (e.g., many people worried about being exposed to other patients and avoided going to medical centers; safety rules prevent physician from physically approaching patients).
- Fast-moving medical threats prevent training medical teams with new techniques and tools; remote medicine helps close such a gap.
- Demand for wearable technologies is growing in response to increasing healthcare costs, aging populations, and the burden of chronic disease.
- AI, ML and big data analytics in cost-efficient, power-efficient electronics and software enable the usefulness of sensor data.

Opportunities

- Increasing availability of faster communications enables extensive use of video conferencing, remote MRI, remote sensors, etc.
- Cloud computing allows small medical centers to perform computations that require vast compute power.
- Government and insurance company R&D investments will help advance sensors, research, and remote medical infrastructure.
- New classes of machine learning algorithms allow physicians to be more efficient and serve more patients.
- Connectivity improvements, additional type/scope of sensors and further miniaturization to reduce cost and expand usefulness.

Impact

- Broader access to customized solutions and medical assistance
- Technologies that have been developed for COVID-19 will be useful for treating other diseases.

Sustainable solutions / business opportunity

- Integration of wireless charging, energy harvesting, make-on-demand sensors, real-time data analytics.
- Improved reliability and accuracy of sensor data & information analytics.
- Expansion of the application & use of wearable technology.
- The unfortunate likelihood of continuing and future global health crises.
- Enablers: data bandwidth, storage, and access; new ML algorithms and new accelerators to perform sophisticated computations, including at the edge; electronics miniaturization, battery efficiency, advanced sensors, microfluidics, advances in commercial IoT market.
- Inhibitors: cost, the need for explainable ML algorithms, health insurance models/infrastructure, regulatory requirements (e.g., HIPAA, pre-market approval, biocompatibility testing), data privacy & categorization, parts obsolescence / life-cycle, data processing.

2. Augmented Reality

Seamless integration between the real world and cyberspace will increasingly materialize.

Problems/Demand

– Hybrid reality bringing together real and virtual reality.

– Renewed post COVID-19 and due to 5G (leading to 6G, 2030).

– Augment knowledge, capability, options, experiences.

Opportunities

– Inclusivity (differently-abled, geographic, cultural, etc.).

– Changing the world of work.

– Augment reality with data, multiple input, simulations, etc.

– Events and Entertainment (conferencing, gaming, movies, tours, art exhibitions, gambling, etc.).

– Education (broader access, broader exposure to ideas).

– Wellness (interactive gym, mental wellbeing, etc.).

– Healthcare (robotic surgeries, remote consultations...).

– Social (metaverse).

– Retail, sports, real estate and architecture, tourism.

Impact

– Redefining the future world of work, entertainment, etc.

– Innovation and Inclusion through a hybrid world.

Sustainable solutions / business opportunity

– Low-cost headsets/hardware.

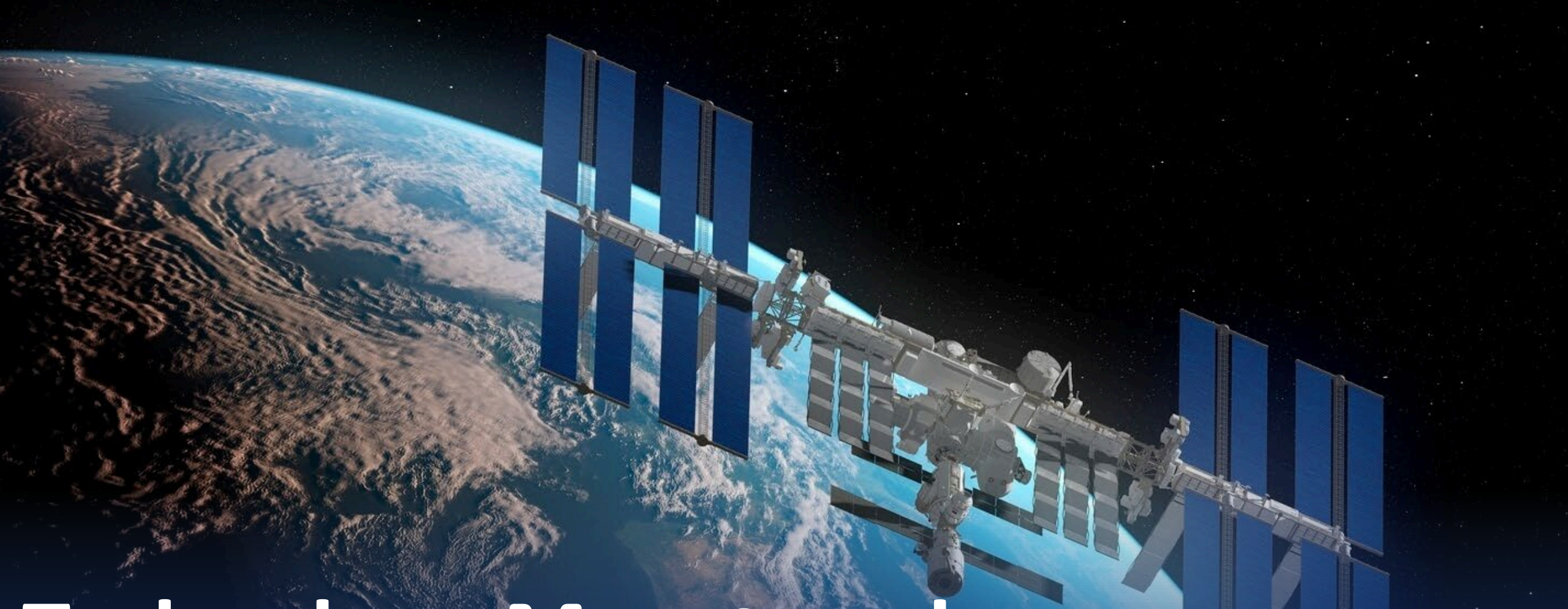
– Education.

– Miniaturization.

- **Enablers:** mind-set post COVID-19, 5G, reduced bandwidth (relative to VR), youth population in emerging economies.
- **Inhibitors**: mind-set (both enabler and inhibitor), digital inequality, lack of standardization, cost of firmware development/maintenance (initial investment or technology adoption – ahead of time), privacy and other legislation/regulatory framework (particularly in a transnational world), data validity (what is accurate, truthful, best), health concerns.

Predictions Scorecard 2016-2022

2022: B/C	2021: B-	2020: B-	2019: B	2018: B	2017: A-	2016: B+
Convergence of HPC, AI, HPDA: **B+**	Remote workforce technologies: **A**	AI@Edge: **A-**	Deep learning accelerators: **A**	Industrial IoT: **A+**	AI, ML, cognitive computing: **A+**	Advanced ML: **A**
Datacentric AI: **B+**	HPC as a Service: **B+**	Additive manufacturing: **A/B**	Assisted transportation: **A/B**	Accelerators and 3D: **A**	Accelerators: **A**	Data Science: **A**
Remote Medicine: **B+**	In-memory computing: **B+**	Adversarial ML: **B+**	Virtual (VR) and augmented reality (AR): **B+**	Blockchain: **A**	Blockchain (beyond Bitcoin): **A**	Containers: **A**
Digital Twins in Manufacturing: **B**	ML for additive & subtractive manufacturing: **B**	AI and critical systems: **B+**	Active security protection: **B**	Deep Learning: **A-**	Sensors everywhere and edge computing: **A-**	Cyber Physical Systems: **B+**
Health, Safety, Wearable Biomed Tech: **B**	Advanced cyberweapons: **B**	Non-volatile memory products, I/F, applications: **B**	Chatbots: **B**	Assisted Transportation: **A-**	Industrial IoT: **B+**	Virtual and Augmented Reality: **B+**
Safety for Autonomous Systems: **B-**	Social distancing technologies: **B**	Legal related implications to reflect security and privacy: **B**	Social credit algorithms: **B-**	Robotics: **B+**	5G: **B**	5G: **B**
3D Print in Healthcare: **B-**	Reliability/safety for intelligent autonomous systems: **B-**	Digital Twins, including Cognitive Twins: **B-**	The Internet of Bodies (IoB): **B/C**	Assisted reality and virtual reality (AR/VR): **B-**	Hyper-converged systems: **B**	Network Function Virtualiz. (NFV): **B**
AI@Edge, Federated Learning: **B-**	Synthetic data for training ML systems free of bias: **B/C**	Reliability and Safety for Intelligent Systems: **B/C**	Advanced (smart) materials & devices: **B/C**	Ethics, laws, policies for privacy, security, liability: **C+**	Self-driving cars: **B-**	Nonvolatile Memory: **B-**
Trustworthy AI: **B-**	Low latency virtual musical rehearsal & performance: **B/C**	Practical delivery drones: **B/C**	Technology for humanity (specifically ML): **B/C**	Cybersecurity and AI: **C**	Disaggr./fabric-attached nonvolatile memory: **C+**	Capability-based Security: **C**
Metaverse: **B/C**	Disinformation detection: **B/C**	Applying AI to Cybersecurity: **B/C**	Automated voice spam (robocall) prevention: **C**	Digital Currencies: **C-**		
Confidential Computing: **B/C**	Trustworthy and explainable AI/ML: **C+**					
Cybersecurity of Critical Infrastructure: **C+**	Election security / social media controls: **C**					
Commoditization of Space Tech: **C+**						
Low-Code/No-Code: **C+**						
Disinformation Detection/Correction: **C**						
Non-Fungible Tokens (NFTs): **D+**						



Technology Megatrends
Predictions, Insights, and Recommendations

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Status

Documents and press releases

- 2022 Technology Predictions Scorecard released in December
- 2023 Annual Technology Predictions released mid-January (input to megatrends)

Megatrends articles in IEEE Computer

- "Virtual Worlds (Metaverse): From Skepticism, to Fear, to Immersive Opportunities," P. Faraboschi, P. Laplante, D. Milojicic, R. Saracco (July 2022)
- "Sustainability, Fundamentals-based Approach to Paying it Forward," C. Bash, N. Hogade, D. Milojicic, G. Rattihalli, C. D. Patel (October 2022)
- "Digital Transformation, Lights and Shadows," Paolo Faraboschi, Eitan Frachtenberg, Phil Laplante, Dejan Milojicic, Roberto Saracco (January 2023)
- "Megatrends", (April 2023)

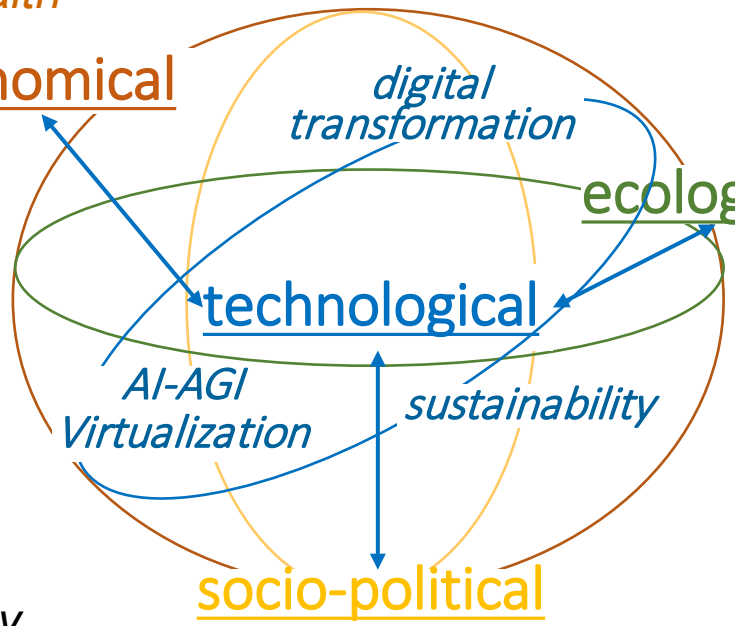
Panels and Talks

- Presentation to Lockheed Martin, December 2022
- Panel at GlobeCom 2022, December 2022
- IEEE Future Tech Forum on Future of Workforce, December 2022
- ICCE 2023 Panel How Megatrends Drive Innovations in Consumer Technology
- CCNC 2023 Panel How Megatrends Drive Innovations in Consumer Technology

What does constitute a Megatrend?

- A megatrend has an impact on the evolution of multiple trends, hence the importance to understand Megatrends
  - it is both the sum and a guiding force since usually it leads to a perception that influences its components
- A megatrend impacts multiple factors, substantially
  - technological
  - economical
  - social
  - ecological
- Megatrend **is not**
  - temporary fashionable technology
  - coming from a single contributing society
  - of interest to a limited region or a group
- A megatrend **is**
  - of global, world-wide importance → Political
  - critical enough that will require regulation
  - encompasses multiple technologies
  - evolving over a few years if not decades

Technology Megatrends vs General Megatrends



emerging markets

emerging global wealth

shifting economic power

globalization

increasingly multipolar world

mobility

rapid urbanization

aging population health

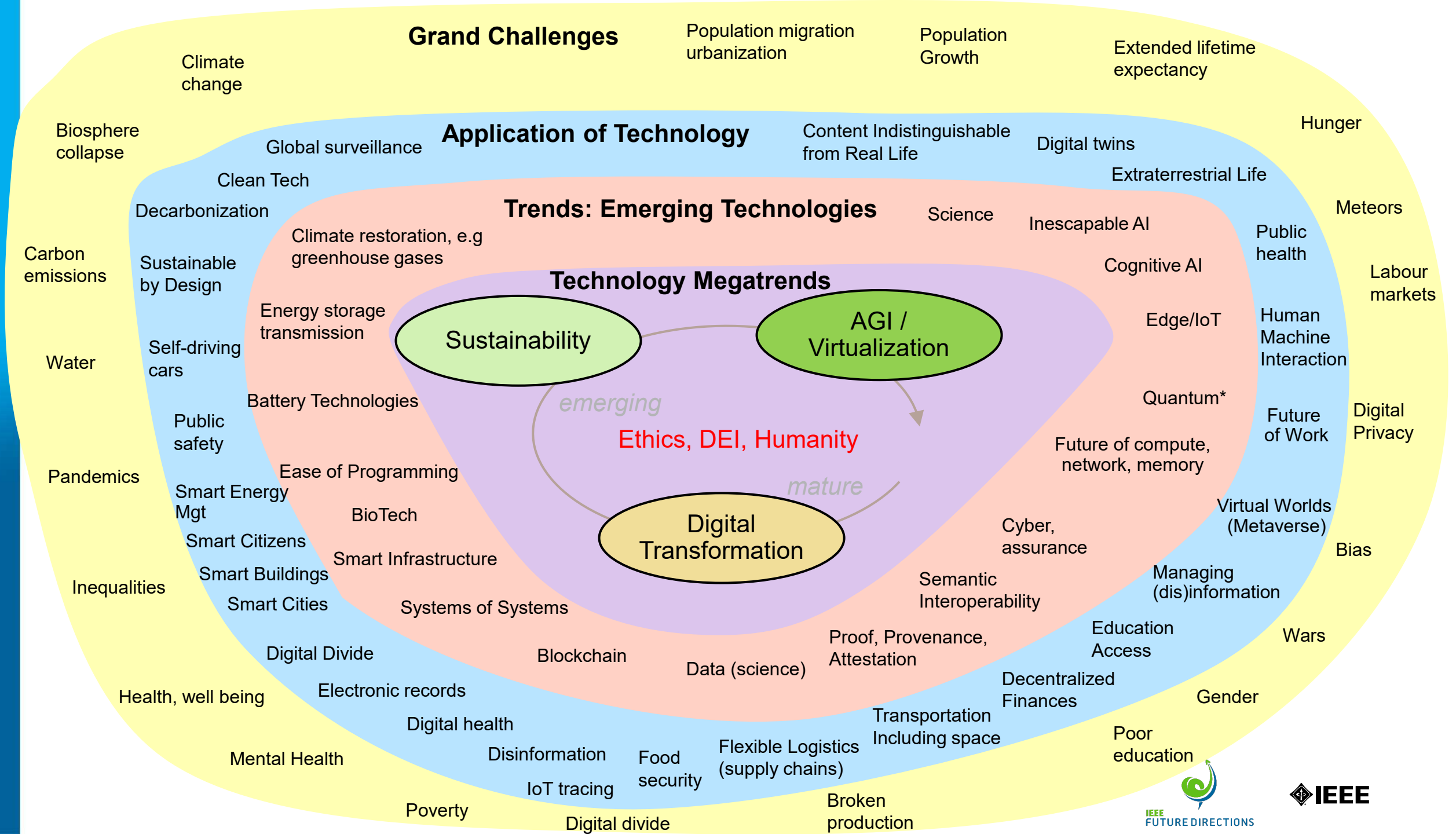
increasing environmental pollution

climate change and resource scarcity

synthetic biology

changing disease burdens, risk of pandemics

demographics and social change


Grand Challenges
Climate change
Population migration urbanization
Population Growth
Extended lifetime expectancy
Hunger
Biosphere collapse
Application of Technology
Global surveillance
Content Indistinguishable from Real Life
Digital twins
Extraterrestrial Life
Clean Tech
Trends: Emerging Technologies
Decarbonization
Science
Inescapable AI
Meteors
Public health
Carbon emissions
Climate restoration, e.g greenhouse gases
Sustainable by Design
Cognitive AI
Labour markets
Technology Megatrends
Energy storage transmission
Sustainability
AGI / Virtualization
Edge/IoT
Human Machine Interaction
Water
Self-driving cars
Quantum*
Battery Technologies
emerging
Public safety
Future of Work
Digital Privacy
Ethics, DEI, Humanity
Future of compute, network, memory
Pandemics
Ease of Programming
mature
Smart Energy Mgt
BioTech
Digital Transformation
Virtual Worlds (Metaverse)
Smart Citizens
Cyber, assurance
Bias
Smart Infrastructure
Smart Buildings
Semantic Interoperability
Managing (dis)information
Inequalities
Smart Cities
Systems of Systems
Education Access
Wars
Proof, Provenance, Attestation
Digital Divide
Blockchain
Data (science)
Decentralized Finances
Health, well being
Electronic records
Gender
Digital health
Transportation Including space
Poor education
Mental Health
Disinformation
Food security
Flexible Logistics (supply chains)
IoT tracing
Broken production
Poverty
Digital divide
IEEE FUTURE DIRECTIONS
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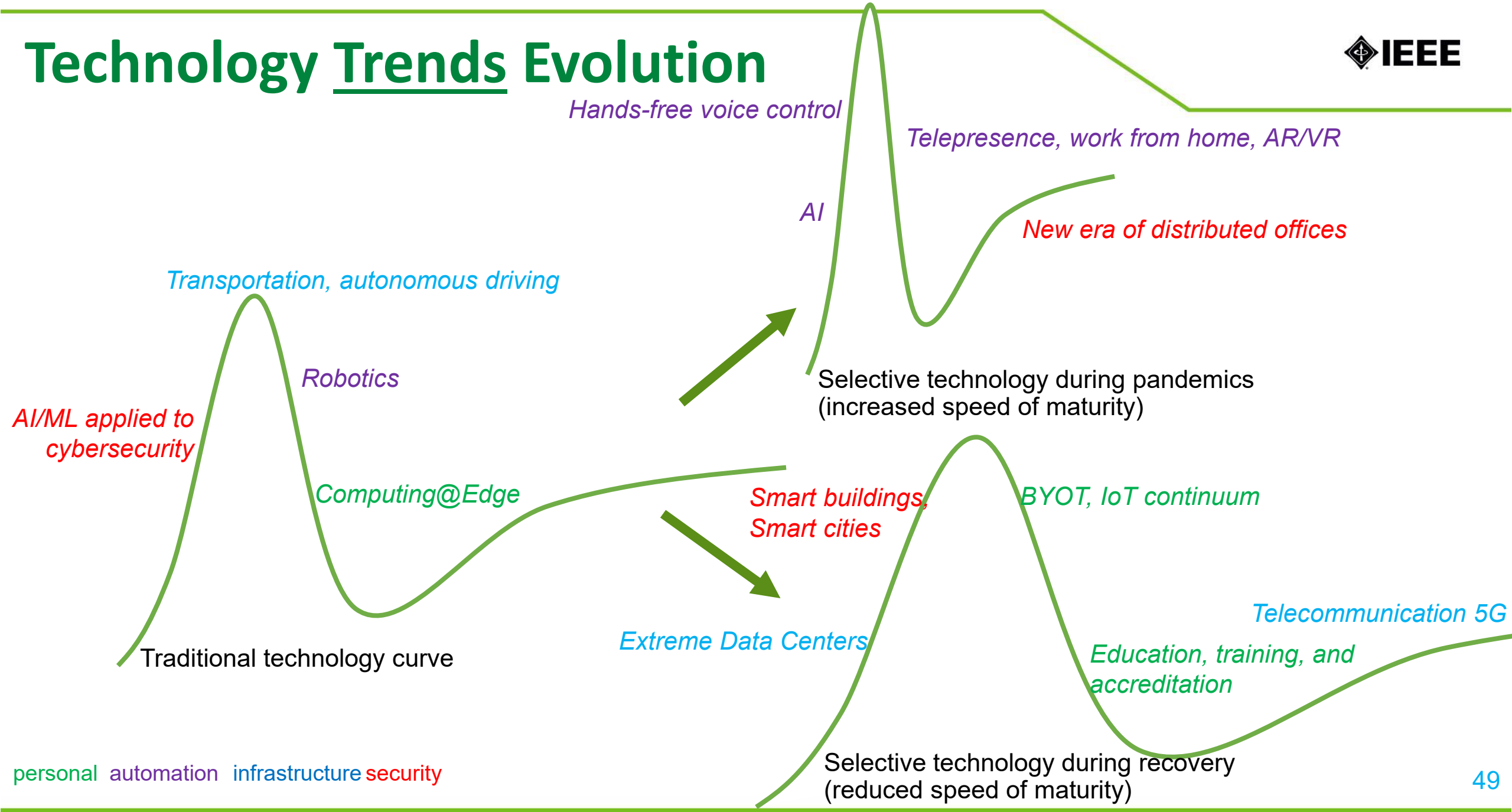
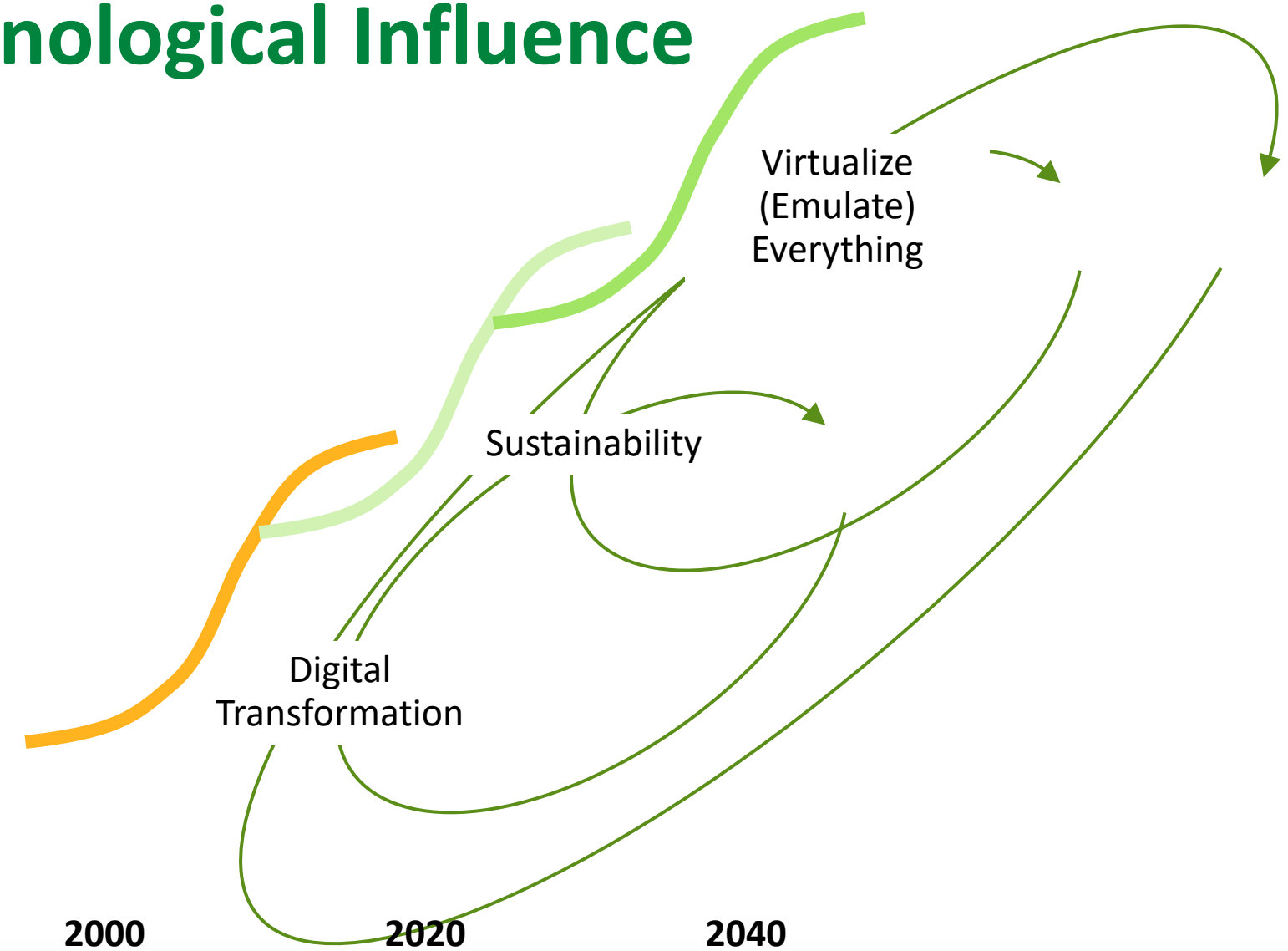
Technology Trends Evolution

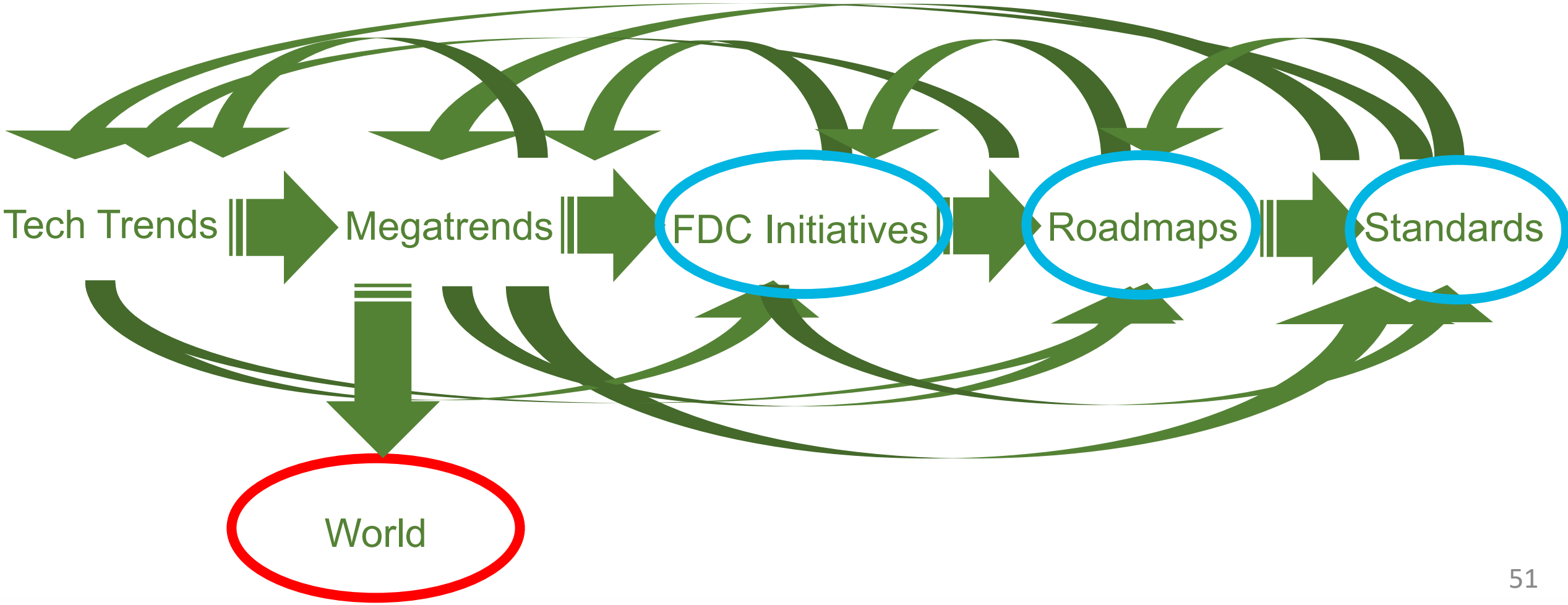


personal automation infrastructure security

Megatrends Adoption Evolution (S-Curves) and Technological Influence



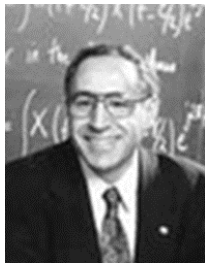
Trends in the broader context



Process

Present impact to humanity as a function of technology advancement, relative maturity, market adoption and time-to-adoption

- Selection
  - FDC-IAB internal team comes up with a list of the following key technologies (per megatrend) that will advance over next year: a) horizontal core technologies; b) industry verticals; c) key gaps
  - FDC-IAB external team reviews and extends
- Grading
  - (A-F) for:
    a) Predicted Technology Success in 2024;
    b) (Potential for) Impact to Humanity;
    c) Predicted Maturity in 2024;
    d) Predicted Market Adoption in 2024.
  - (1 year, 3y, 5y, 10y, 15y) for Horizon to Commercial Adoption.
- Qualifying
  - For each selected technologies, prepare a slide: problems/demand, opportunities, impact, and sustainable solution/business opportunity.


Metin Akay, many volunteer positions


Ravikiran Annaswamy, CEO and CoFounder, Numocity Technologies


Klaus BEETZ, CEO EIT Manufacturing


Kirk Bresniker, Fellow/VP Hewlett Packard Enterprise, HPE Labs Chief Architect


Matt Bross, Partner CloudScale Capital Partners, Chairman CEO - IPX Advisors,


Valerie Browning VP Research & Technology Lockheed Martin


Celia Desmond, IEEE volunteer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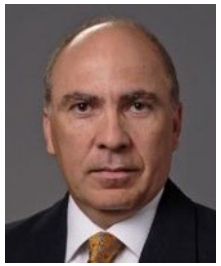
Luigi Gambardella Reed College


Gabriele Elia, Head of Technology Communication & Standardization at TIM, Turin


Stephen Dukes President of Dreamerse


Gustavo Giannattasio, many volunteer positions


Eric Grigorian, P.E., PMP, GTRI, Aviation Systems Division Chief Engineer


Kathy Grise, Future Directions, Senior Program Director at IEEE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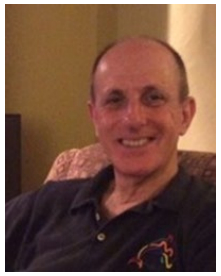
Mazdak Hashemi, Ex VP Engineering Twitter


Steve Keckler, Vice President of Architecture Research at NVIDIA


Rakesh Kumar, IEEE Roadmaps chair


Witold Kinsner Professor ECE University of Manitoba


Luis Kun President 2022 IEEE SSIT


Phil Laplante PSU, NIST


Tim Lee, Boeing Fellow


Gabriel Loh, Senior Fellow Advanced Micro Devices


Deepak Mathur, ONGC, Chief General Manager (retired)


Dejan Milojicic (chair) Hewlett Packard Ent.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Damir Novosel, President Quanta Technology


Paul Nikolic, Chair IEEE 802 LMSC


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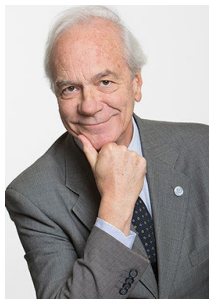
Jeewika Ranaweera, FDC Vide-chair


Paul Reynolds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2023 Technology Megatrends Team

Statements in this slideset express opinions of authors themselves only and not of their employers

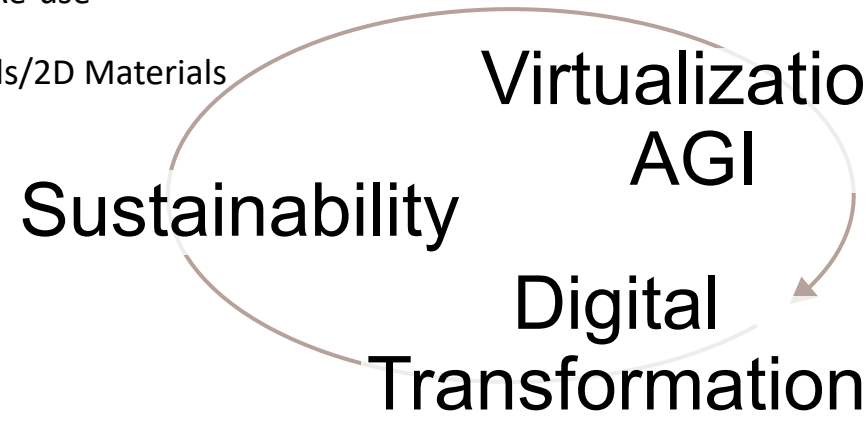
IEEE FUTURE DIRECTIONS

IEEE

Key technologies contributing to Megatrends (Work in Proress)

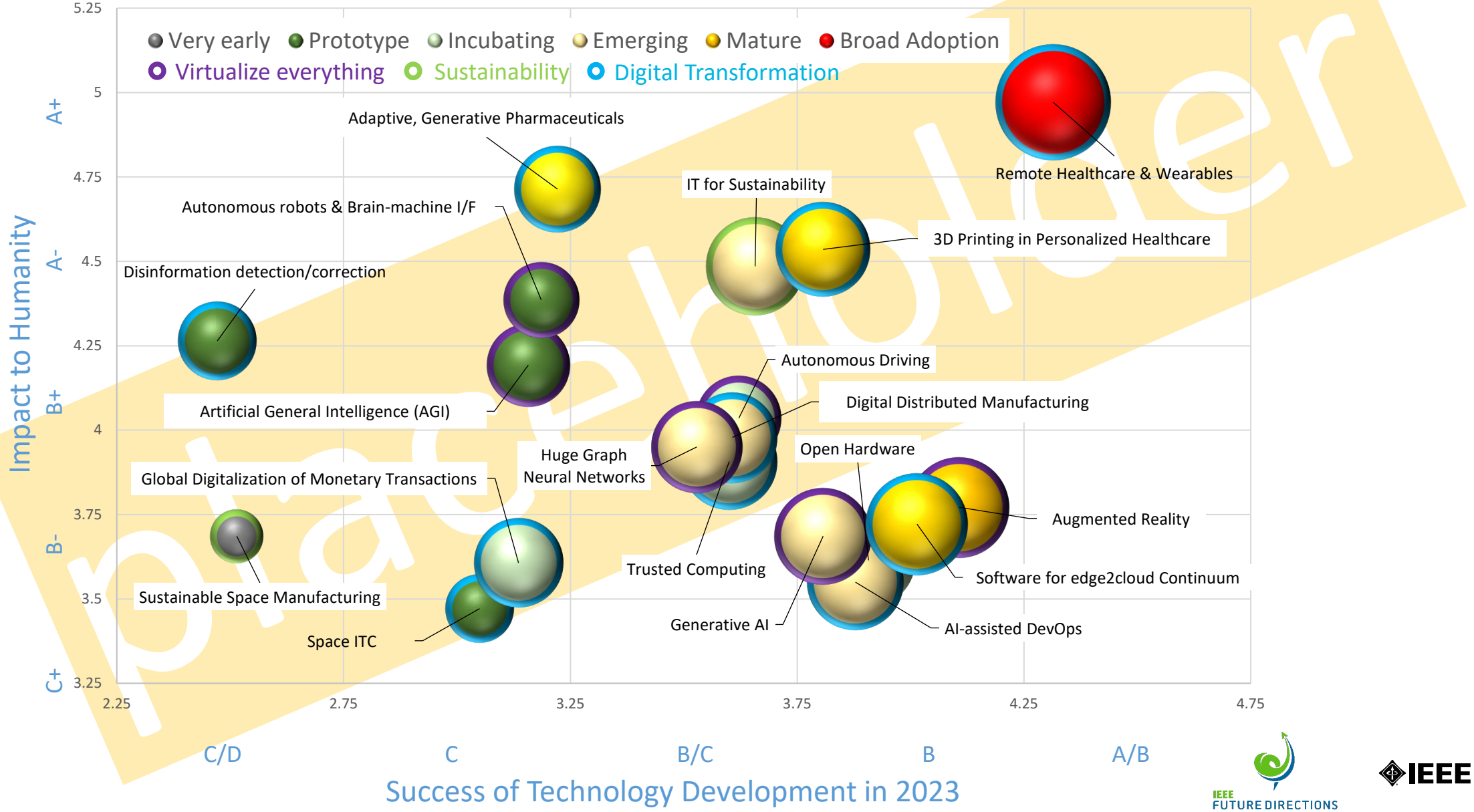
1. Clean renewable energy, Energy Harvesting
2. Sustainable IT and IT for sustainability
3. Energy Storage/Battery technologies
4. Silicon photonics, optical networking
5. Quantum Computing/Quantum Optics/Imaging
6. Biotechnologies
7. Sustainable Manufacturing, Recycling/Re-use
8. Electrification
9. Nanotechnologies, Smart Metamaterials/2D Materials
10. Carbon Capture, Decarbonization
11. Demand Flexibility

1. Digital worlds
2. Computer brain I/F
3. Space technologies
4. AGI
5. Digital Twins
6. Wearable and Implantable Technologies
7. Data Protection/Privacy/ Cybersecurity/Data Verification
8. Virtual-physical closed loop orchestration automation



1. Digital Distributed Manufacturing/Additive Manufacturing
2. Autonomous technologies, Self-* (e.g. Self-driving transportation)
3. Smart environments (City, Home, Lighting, …)
4. ChatGPT
5. Ubiquitous Connectivity/Communications/Cellular
6. Power & Energy Digital Transformation
7. Genomics/Gene Repair/DNA Medicine/Molecular Medicine
8. Digital Training/Service Training
9. Healthcare/Digital Health/Remote Healthcare/Personalized Medicine

Technology Success (x-axis) vs Impact to Humanity (y-axis) (size of bubble proportional to relative market adoption)



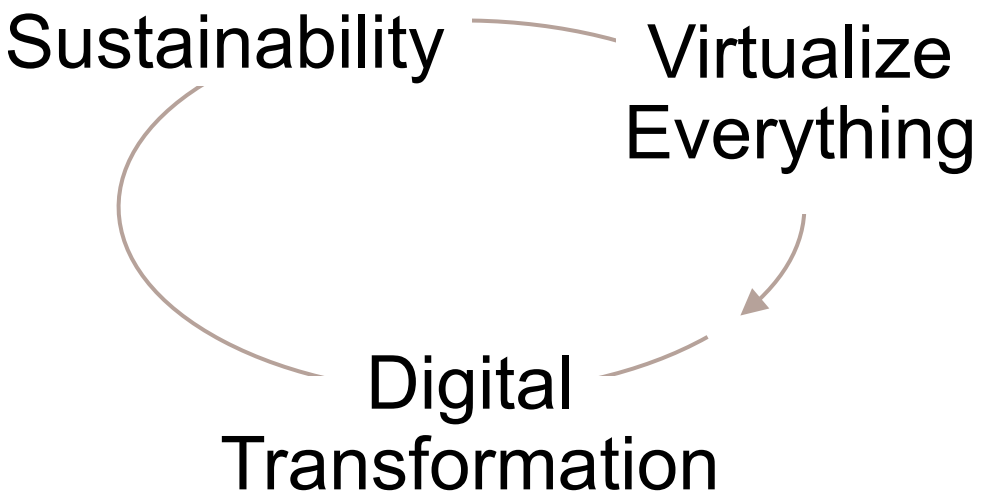
IEEE FUTURE DIRECTIONS

IEEE

Generic Recommendations to Industry, Government, Academia, & IEEE

INDUSTRY
- Increase transparency and openness of processes for other players to participate
- Abide by open-data harvesting policies and make it transparent and easy to customers to understand
- Establish digital markets for products and services

ACADEMIA
- Innovate in terms of practical processes, policies and regulations
- Model large scale systems, increase use of data-driven AI to augment functionality and improve accuracy
- Explore extreme requirements, e.g. real-time, reliability, acting in space
- Explore humans in the loop for AI



GOVERNMENT
- Introduce practical regulations on technology and data usage
- Introduce incentives to follow regulations and policies (balance enforcement and incentives)
- Coordinate international, cross-border regulations
- Define and regulate use of AI, without stifling innovation

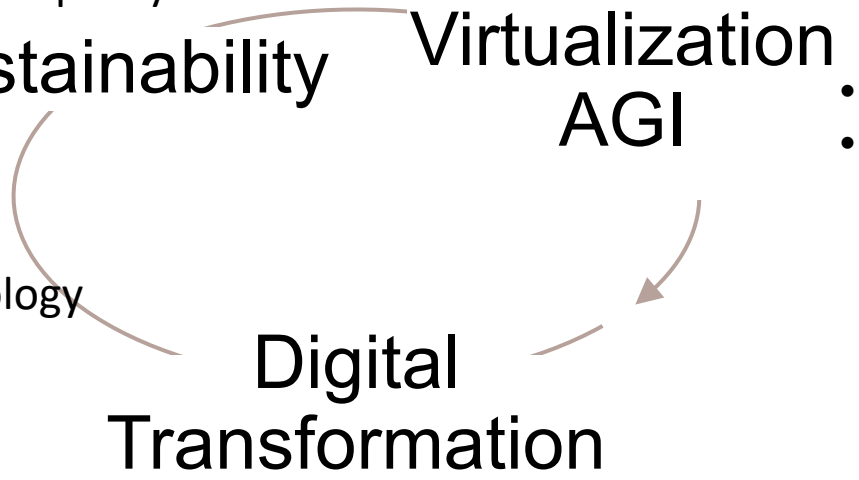
PROFESSIONAL ORGANIZATIONS (such as IEEE)
- Define standards and best practices, gathering support from the various stakeholders
- Recommend technology adoption roadmaps
- Convene industry, governments, and academia to innovate and advance technology

IEEE FUTURE DIRECTIONS

IEEE

Megatrend-specific Recommendations (Work in Progress)

- Identify scopes 1-3 for own organizations
- Set credible targets to reductions
- Devise executable plans for footprint reductions
- Redefine new measures for success
- Create new governance framework
- Innovation for health accessibility and disparity
- Measure footprints
- Address quality of life
- Protect the environment
- Disaster prediction and prevention
- Safe transport of dangerous materials
- Design new paths for equitable technology dissemination

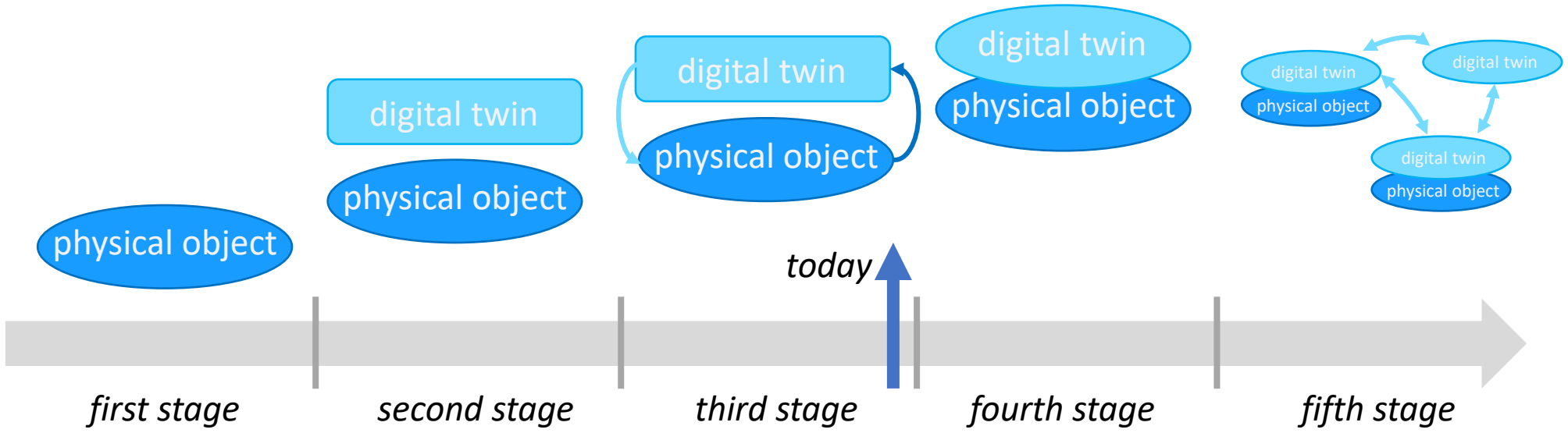


- Learn, try
- Compare test
- Innovative uses
- Facilitate learning of novel technologies
- International research of data lakes
- Facilitate universal knowledge acquisition and distribution
- societal workforce impact by AGI
- Identify and support novel technology excellence (workforce)

- Do the inventory
- Best practices
- Cost/opportunity analysis
- Generate landscape for verticals
- Increase ability to store data and capability
- Expose and fight disinformation
- Develop technologies to address digital divide and disparity (equity)
- Integrate across the enterprise
- Manage full lifecycle of systems of systems

Digital transformation evolution

(TO DO: equivalent individual ones for sustainability/virtualized, then w/ integrated)



Evolution for Sustainability (Work in Progress)

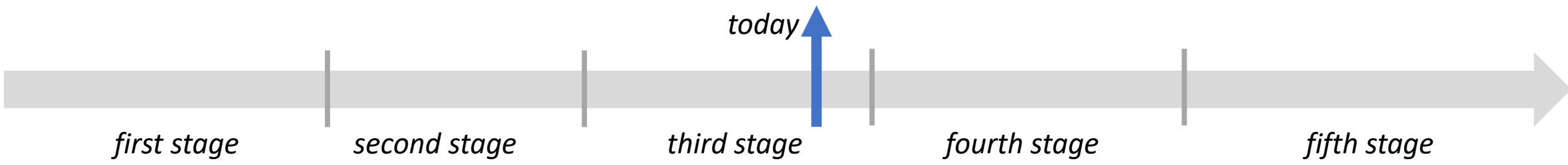
1. Universal acceptance of the problem
2. Universal metrics/KPIs
3. Quantification & definition of goals
4. Education cultural transformation
5. STEM Education
6. Standards for taxonomy

1. Extendable service lifecycle (reuse, recycling)
2. Plan for achievable results (roadmap)
3. Sustainability by design
4. Managing disruptions
5. Framework standards

1. Design for sustainability
2. Shorten technology maturation and adoption
3. Use testbed of digital twins for efficient implementation
4. Identify R&D pilot projects
5. Iterative approach
6. Implementation standards

1. Validation & verification standards
2. Pilot project implementation
3. Ethical and economic scaling
4. Technology implementation

1. Technological consolidation
2. Dissemination of validated technology
3. Portfolio approach
4. World we envision
5. Speed to implementation



What about AI?

- AI transpires
  - all megatrends
  - other global megatrends
  - technologies comprising technology megatrends
- AI impacts all three principles
  - Ethics, DEI, Humanity

Digital Transformation

Problems/Demand

- The quest for efficiency and flexibility by most sectors (industry, healthcare, construction, cities…) is pushing towards the shift to the cyberspace. Transactions in the cyberspace are quick and cost very little.

Opportunities

- Shifting processes and activities to the cyberspace opens up new revenue opportunities (althogh it cuts part of the existing ones, particulalry looking at the whole value chain)
- The presence of sensors in the ambient, in equipment on the shop floor and more and more embedded in products seamlessly connected to the cyberspace through a pervasive communication infrastructure (4G, 5G, WiFi, …) makes possible the operation of physical entities through their digital counterpart (Digital Twins) These, in turns, can operate and co-operate in the cyberspace

Timeframe

- It is already happening, in certain areas it has already happened (like in the entertaiment, tourism areas). By the end of this decade most business will have shifted to the cyberspace. The pandemic has first pushed many companies to use the cyberspace, than it proved that this is both feasible and effective. We are now seeing a few company moving back to the physical space but it is for everybody a new normal and the path is clear.

Key Driver

- Economic and societal push balancing effectiveness with sustainability

Trends, Application, Grandchallenges

- Increased uptake, applied in every field. Managing the transition and surviving it is the greatest challenge.

Impact

- Every business is being impacted, with side effects on jobs (both loss of jobs and new openings, usually requiring new skills)
- Shift from product to service oriented business models
- De-localisation of intellectual resources
- Lower transaction cost, leading to increased competition and shorter product (service) life time

Sustainable solutions / business opportunity

- Almost all vertical industries are going through digital transformation
- Enablers: technology, data spaces, artificial intelligence
- Inhibitors: regulation framework, inertia, safeguards of present jobs …

Sustainability

Problems/Demand

- Increased society decarbonization to address climate change
- Clean energy to support public health
- Reliable and resilient energy delivery
- Affordable prices
- Energy justice

Opportunities

- Energy and fuel transformation
- Electrification: transportation, buildings, industry, and agriculture
- Energy efficiency and demand response

Timeframe

- Now-5 years out

Key Driver

- Societal push towards clean energy, but also industrial need for economically sustainable solutions

Trends, Application, Grand Challenges

- Decarbonization
- New distributed energy resources (DER), batteries, new energy transmission and storage
- Carbon emission, hunger, climate change

Impact

- Reduction in carbon emissions to combat climate change
- Clean environment
- Increased resilience to natural disasters (hurricanes, fire, tsunamis, earthquakes, etc.)
- Achieving affordability
- Quality of life equity

Sustainable solutions / business opportunity

- Engage various stakeholders in achieving goals
- Identify technology and business solutions to mitigate GHG emissions
- Adaptation strategies to address climate change
- Prioritize initiatives to reach targets and have most effective impact
- Enablers: Technology developments (electrical vehicles, solar, and wind generation, electrical storage, controls, communications, SW/HW tools). IEEE ability to communicate key technology solutions and connect key stakeholders global. Benefit from standardization. Energy storage solutions to bridge consumption and production cycles.
- Inhibitors: Business and politically biased environment promoting self-interests. Using incorrect technology reasons to prevent progress. Inefficient battery energy storage solutions depending on rare earth metals resulting in environmentally harmful mining and geostrategic dependence on extraction monopolies.

Virtual Worlds (Metaverse)

Problems/Demand

- The COVID-19 pandemic' need for physical distancing, increasing workforce globalization, and the higher connectivity of people across distances are driving demand for immersive remote-presence technologies
- Scale of technologies prevents development and testing of largest deployments
- Cost of physical world is prohibitively expensive for many solutions
- A lot of places are inaccessible for physical presence
- A Digital Twin is an exact virtual representation of a real-world system or object, it
  - pairs virtual/real world and allows for real-time analysis/monitoring remote/inaccessible objects
  - can enhance an organization's ability to make data-driven decisions, increasing efficiency
  - enables experimenting with the future by exploring scenarios safely, economically, & sustainably

Opportunities

- Large scale gaming
- Predictive maintenance; test & verification of functionality before a system/product is built
- Iterative improvements/optimizations by exchange between virtual and physical worlds
- Facilitate proximity-based or spontaneous collaboration, substituting office environment
- Technology to facilitate remote learning, substituting for the classroom environment
- Facilitate effective large-scale meetings, substituting for the conference environment
- Large increase in recreational and social time spent in the virtual world

Timeframe

- Now-5 years out

Key Driver

- Gaming industry,

Trends, Application, Grand Challenges

- Decarbonization
- New distributed energy resources (DER), batteries, new energy transmission and storage
- Carbon emission, hunger, climate change

Impact

- Accelerating innovative product and process design
- Virtual world has already taken place in many industries with avatars
- Broad scenario exploration to improve usability and safety; Solving problems before they occur, predictive maintenance; Increased adoption of autonomous systems
- Faster transition from "back-to-the-office" to "work anywhere" mentality
- More effective social distancing to curb pandemics
- Reduced travel & carbon footprint
- Potential loss of privacy expectations from physical meetings

Sustainable solutions / business opportunity

- Substantial impact in product/process quality improvement, reduced operation cost
- Improved VR/AR technologies help bridge physical distancing
- Mitigation of the productivity hits from the loss of collaborative office work
- Increased opportunity for a global and diverse workforce ("hire anyone, anywhere")
- Enablers: low-latency immersive VR; enhanced sensory experience (smell, touch, taste); sensors for data collection; and networks to transport vast amounts of sensor data; reliable broadband. 3D virtual environments, machine learning. The emergence of open metadata platforms (like DVC) and a data-centric AI movement, improved data acquisition through IoT and 5G, data pipeline and simulation tools.
- Inhibitors: decreased personal privacy and freedom; insufficiently reliable broadband may lead to VR that causes physical harm; inadequate immersion technology/device fatigue getting in the way; cost to consumers; bridging the gap between the virtual world (simulation) and the real world - ability to accurately model physical property; proprietary platforms; slow adoption of AI de-facto incompatible standards; inability to define "unbiased"; synthetic data too expensive and removed from reality; lack of skilled "data workers"; lack of trust in synthetic training data

Summary

- Technology predictions and Megatrends continue to attract wide audiences across industry, academia, governments, and professional organizations
- Beside “interesting” dimension, they are gaining strategic economical, ecological, and socio-political influence
- We continue to deliver successful predictions in a variety of forms, some non-traditional, e.g. press releases has target audiences of 200M

Thank You!

Questions?

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