Future of the Workforce

Martin Arlitt, Micro Focus
Thomas Coughlin, Coughlin Associates
Paolo Faraboschi, Hewlett Packard Labs
Eitan Frachtenberg, Hewlett Packard Labs
Phil Laplante, Penn State
Dejan Milojicic, Hewlett Packard Labs
Nita Patel, Otis
Roberto Saracco, IEEE Future Directions Committee

The global COVID-19 Pandemic caused tremendous stress in many facets of our existence from global shifts to daily life-altering impacts. Most significantly, the pandemic caused many people and organizations to re-think how they worked, i.e., the pandemic was a forcing function.

Abstract

The pandemic abruptly altered our thinking on supply chain logistics, manufacturing, and privacy. In some instances, the shift caused an acceleration of the digital transformation and in others, technology simply provided a digital crutch. Debates have blossomed on remote, hybrid or in-person interactions along with discussions of which technologies play a crucial role in the Future of Workforce (FoW).

For those of us in "white collar"/ "information worker" professions who already worked from home on a regular basis, little changed. For many others, changes came quickly; Adapting was easier for some and more difficult for others (e.g., for those who didn't already have a good home office set up or had to share desk space with others in their household).

People employed in "blue collar" jobs may not share the same opinions about our FoW recommendations, but we believe that a large percentage of these jobs will grow more "information heavy" in nature.

***Keywords**: Emerging technologies; Information technology; Office automation; Knowledge acquisition; Computers and Education; Social Issues; The Computing Profession; Education; Virtual reality*

Process

This report explores the effects of the pandemic on the FoW and highlights how the world is changing, influenced by a combination of many economical, ecological, technological, and societal factors, all impacting the workforce *[4][13][14][15][16][17]*. Factors were chosen by authors based on literature survey. We then explore enabling technological innovations that brought and continue to bring a major shift in the FoW beyond the pandemic. For each factor and for each technology, we identify

problems/demand, opportunities, impact, and sustainable solution/business opportunities, including enablers and inhibitors.

Our hypothesis is that a combination of these factors and enabling technological innovations will result in a major shift in the FoW, a shift that will persist beyond the pandemic *[10][12]*. Addressing these changes will require educating and influencing global industries, academia, and governments through recommendations for adjustments *[7][8][15]*. This is the goal of this work.

Finally, we make recommendations to stakeholders that can help in this transition: industry, academia, governments, and professional organizations. In each case, both organizations and individual employees are included as stakeholders. One reason to include "workers" as stakeholders is that pandemic enabled many workers to have a flexibility they didn't have before. For example, many people moved to lower-cost locations [18]. Both flexibility and opportunity to improve their standard of living are things that workers will likely not want to relinquish. Our approach for recommendations is depicted in Figure 1.

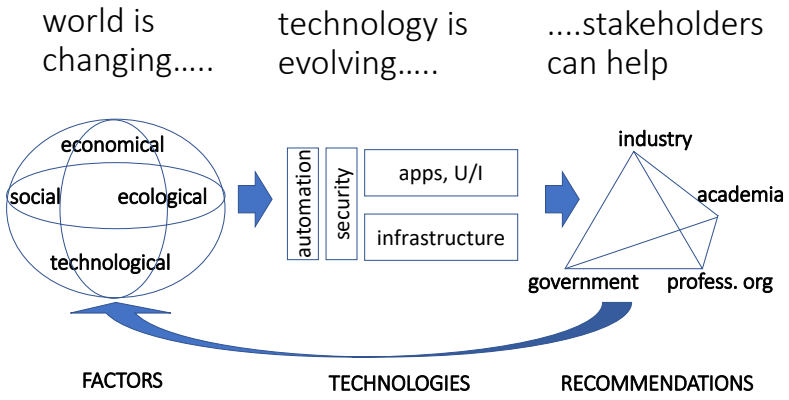

Figure 1. Our Approach

To verify our assumptions about factors and technologies and to expand on our initial set of recommendations, we held ten panels around the world: (1) Singapore in December 2020; (2) India in January 2021; (3) China in March 2021; (4) Sub-Saharan Africa in mid-April 2021; (5) Latin America in late April 2021; (6) Europe, Middle East and Northern Africa also in late April 2021; (7) Northeast US in June 2021; (8) West and Midwest US in June 2021; (9) Canada in August 2021; and (10) Southeast US in September 2021. The main discussion points/questions asked during the panels were recommendations to industry, and government.

We did not follow IEEE internal regions but rather logical groupings. Except for Singapore, which was the first event, we followed countries from east to west, in many ways advancing from emerging and recently established workforce markets to historically established markets.

Following the panels, we conducted a survey of approximately 15,000 people, inviting their assessment of selected factors and technologies, as well as seeking open-ended opinions on the FoW. We summarize both in the remaining text and present the ranking and correlation of factors and technologies. Detailed demographics of both panels and survey are beyond the scope of this paper and could be found in report [1].

A more detailed report will be available from IEEE Computer Society [1]. It took us almost 2 years to complete this research. One year to conduct the 10 panels and an additional year to conduct the survey and write the report. With its scope, size, and hopefully, impact, this reminds of an equivalent report we wrote in 2014-2015 predicting the future of 23 technologies in 2022 [2]. For the 2022 Predictions, we also published a lengthy report and a paper in *IEEE Computer* [3].

Key Factors Influencing Future of Workforce

There are many factors that impact the modern workforce, including societal, such as the drive to increase inclusion, diversity, and pay equity in employment [5]. Additionally, the workforce is increasingly global, especially with so much remote work during the pandemic. Work today requires the ability to quickly change what a worker does, requiring not just continuing education, but rather *perpetual education [8]*. With a more diverse workforce and with greater geographical diversity, establishing trust between co-workers is especially important (i.e., developing meaningful working relationships without physical proximity), as well as developing common ethical standards.

Economic factors are important as well. These include changes in the ways that business is done, resiliency of complex supply chains in the face of rapidly changing demand and the growing importance of emerging economies. At the same time, innovation hubs in many countries encourage economic development. Another dimension is unleashing "stranded talent"; i.e., bringing jobs to underemployed regions of a country without requiring a huge financial investment/risk to a company. Even though technology is changing our dependencies on many raw materials, we still need resources that may be in a wide variety of locations. This resource dispersion is complicated by changes in the international balance of power and political machinations.

Ecological factors are becoming increasingly important as many countries create policies to reduce greenhouse gas emissions and combat climate change. In addition, concerns of safety, security, and crisis response (such as the COVID pandemic) will likely grow more common due to international travel and commerce [6]. The plight of refugees fleeing from war, natural disasters, climate change or political persecution are also an important factor in the changing workforce in many parts of the world.

These factors may be handled better or worse depending upon the actions of government, industry and even academia. In addition, technology is playing an increasing role in the future of the workforce and economic opportunities in general. We have only to look at the way technology has allowed remote work for many connected people while those without easy access to the Internet have suffered. Technology is also automating more work, allowing future jobs to increasingly combine humans with machines. We summarize these factors in Table 1 and more details can be found in the full report [1].

Table 1. How is the World Changing?

Economical	Global just-in-time supply chains → Regional, home-bound deglobalization, plan B
	Global industry production → Customized regional products owning tech
	Regional workforce market → Crowdsourcing cutting global boundaries
	Supplemental gig economy → Gig economy responsible for individuals
	Benefits/ Corporate → Purpose/ Ecosystem
technological	Automated → Autonomous
	Technical standards → Social-technical standards
	Stove pipes in technology → Interdisciplinary co-design
	Social networks (humans) → Sensor networks (machines)
	Technical advancement → human-centricity and ethical enablement
ecological	Cities, hub & spoke model → Support geo depressed regions
	UN-driven sustainability → Social startups & global industry
	Protect the Planet → Return to the Planet
	Signing the treaties → act collaboratively
	Reactive (to COVID, …) → Preventive
social	White/blue collar → New collars
	Diversity → Diversity, Equity, Inclusion
	People ready for tech → Tech-ready people
	High-tech → high-touch, high-care
	Training → reskilling, upskilling, continued education
	Work as a means of living → Work as a means of fulfilment

Key Technologies Influencing Future of Workforce

Technology is playing an enormous role in transforming how we work and what we do while we work. Personal technology that employees carry with them can be from their organization, or increasingly their own preferred equipment. These include “Bring Your Own Device (BYOD); computing at edge; and personal education, training, and accreditation. Supporting this technological diversity requires an IT infrastructure that can work in a highly heterogenous environment. Employees will use these devices to connect with ubiquitous IoT devices and with computing resources at the network edge, in their workplace, in factories, and in their local infrastructure. Having access to these devices will help workers access useful training when they need it and stay connected even when separated from their coworkers. Lack of access to these devices and the connectivity to use them could create a wider economic divide.

Automation is changing the way we work. Much repetitive and heavy physical work is now being done by robots. This automation can be controlled by voice as well as gestures. Technology will increasingly allow us to interact with machines in new ways. In addition, and likely spurred by the pandemic, remote work using telepresence, augmented reality, and virtual reality could become more popular as they can create a more immersive and realistic interface with others and with equipment. Robot/human combinations are growing in importance, with robots designed to work safely with humans in their vicinity. Future work will involve close collaboration between humans and their AI-enabled software and machines. New jobs and new ways of working will be created from these man and machine collaborations [11].

The infrastructure in countries, cities, and factories is evolving rapidly. With more ADAS (Advanced Driver Assistance Systems) and autonomous driving features, transportation will be transformed. In

addition, ubiquitous high-speed wireless networks and new satellite communication networks will enable more flexible ways to work and new business opportunities. Data centers will become even more impressive in their computation, digital storage, and networking capabilities, while minimizing their carbon footprint through innovative technologies, new computing environments and local sustainable power production. Recent technologies such as quantum computing and blockchain will change the way we solve some business problems and secure the supply chain. AI technology, combined with increasing sensors in our environment, will further enhance and enable new ways to interface with our machines, including real-time support and control using voice or gestures [7].

With so much of the world's economy dependent upon various technologies, securing these technologies will be critical to maintaining the economy and fair and open communication. Various AI tools will play an increasing role in detecting and controlling cybersecurity threats [7]. Quantum-proof encryption will be required in much of our communication between and with the smart infrastructure that will surround and sustain us. Maintaining privacy controls will continue to be important to protect citizens. Ensuring that all this technology infrastructure continues to support us in our everyday lives requires new levels of security and a continuing dedication to defending it from malicious agents. These technology trends are summarized in Table 2 and more details can be found in the full report [1].

Table 2. How is Technology Evolving?

Apps, U/I	Economical divide education → digital divide education
	Corporate IT, devices → Cost Share, BYOD[1], broadband
	Voice recognition → Hands-free Voice Control
	Centralized data analytics → AI@edge
automation	Robots in fenced environment → real-time responsive collaboration
	AI-assisted → Explainable, mission-critical AIOps
	Reusable code, patterns → Low-code no-code
	Virtual and assisted reality → Metaverse
	Telepresence → Digital twins
infrastructure	5G, WiFi6 → drone satellites communication for rural
	Just-in-time production → Additive manufacturing
	Quantum communication → Quantum computing
	Assisted driving → autonomous driving
	Data analytics → Datacentric AI
security	AI-assisted cyber analysts → AI/ML replacing analysts
	Physical protection → Supply chain guarantees
	Privacy-preserving → Privacy-driven
	Bitcoins and digital currency → NFTs

Insights from Ten Panel Sessions around the World

The pandemic has truly been a global force for change, severely affecting industries and individuals alike. After having met with ten panels of industry experts and government officials around the globe, some common themes emerged, and some unique concerns were identified.

[1] bring your own device

Common themes included increased workforce mobility, enabled by the prospect of remote work. Increased mobility allowed for continuation of work, increased flexibility and faster adaptation of technologies and digital tools within the organization. The remote workforce also introduced shared challenges in all regions. These challenges include new methods/techniques for performance management, employee integration and coordination and more flexible social interactions. This situation also appears to be outdated in many organizations, as does the curricula in many places of learning.

Another common theme across these regions was the need for a stable and accessible digital infrastructure across all groups of individuals, types of work and parts of the globe. Although differing technologies enabled opportunities and continued engagement in different areas, the general need for digital access and more education to enable the use of increasingly complex technologies was highlighted in all the regions.

Although access to technology, flexibility & mobility for a remote workforce, increased educational requirements, engagement, and the mental-well-being of individuals were common within all the regions, each region also had a different area of focus. For example, Asian countries (Singapore, India & China) expressed care for individuals as a leading concern while access to broadband was critical in Sub-Saharan Africa and Latin America and a focus on the general workforce was a key concern in India.

Figure 2 summarizes the feedback we identified during the ten panels. More details can be found in the full report [1].

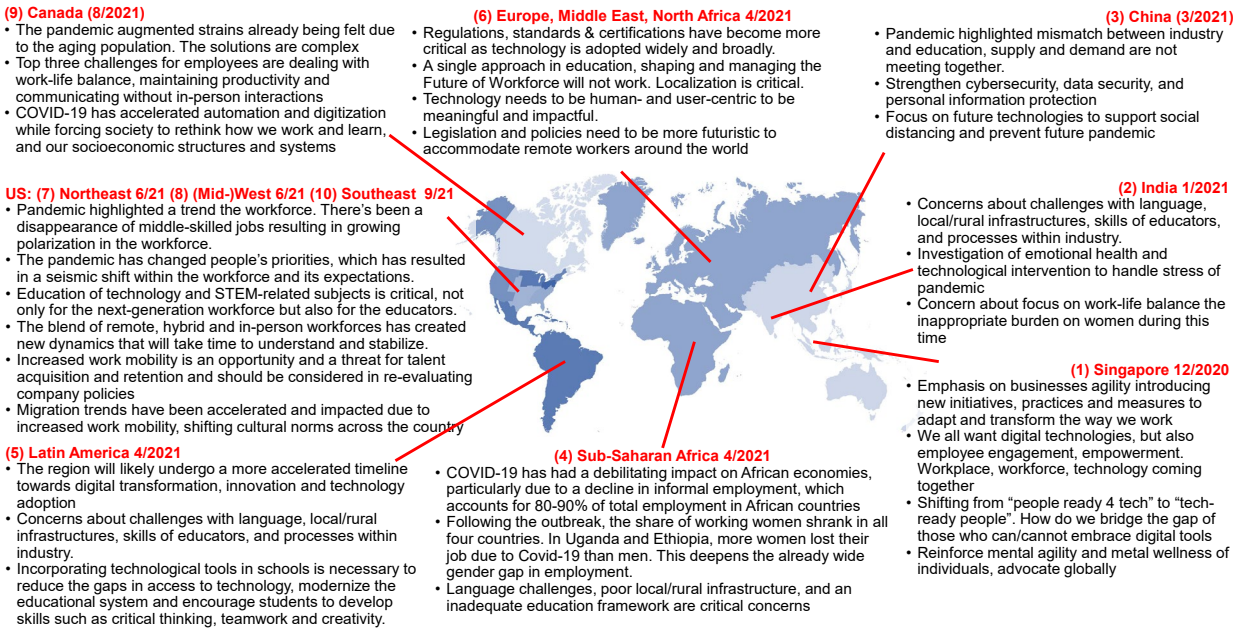

Figure 2. Summary of insights from different regions around the world. The detailed report has more details from each of the 10 sessions.

Insights from the Survey

During fall 2021, we conducted a survey of some 15,000 randomly selected IEEE members, receiving 1,480 responses. We asked about emerging technological, ecological, societal, and economic factors for

FoW, and their likelihood and desirability. We also asked respondents to make predictions on fifteen emerging FoW technologies. Overall, respondents were optimistic about a permanent transition to remote work (especially women, 9.5% of respondents were women, with 23% not declaring gender.) and about global collaboration and markets but were also concerned about personal privacy with remote work. Respondents expect most of the technological changes for FoW to be driven primarily by businesses; governments are expected to take a larger role in green energy, safety, ethics, privacy, and diversity/equity/inclusion.

When plotting factors by how likely respondents think they will trend vs. how desirable they find them (see Figure 3), we find that the two appear positively correlated, i.e., that most respondents view these changes more favorably as their likelihood increases. Two notable exceptions are increases in transparency, which are viewed as desirable but less likely, and geopolitical changes in the balance of power, which are viewed as very undesirable. The parallel chart on emerging technologies (see Figure 4) shows even stronger correlations between likelihood and desirability. It also shows the relatively low desirability of advances in robotics and bringing one's own technology to FoW, as well as the relatively desirable but unlikely technological improvement in education, training, and accreditation.

We also compared factors and technologies to each other, grouped by category (see Figure 5). We found that technologically desirable or likely factors are also perceived as beneficial/likely to society. It is important to keep selection bias in mind: the responding population skews towards private industry, computer and EE expertise, older and experienced, male, and highly educated. As IEEE members, we expect respondents to be optimistic about technology in the service of society.

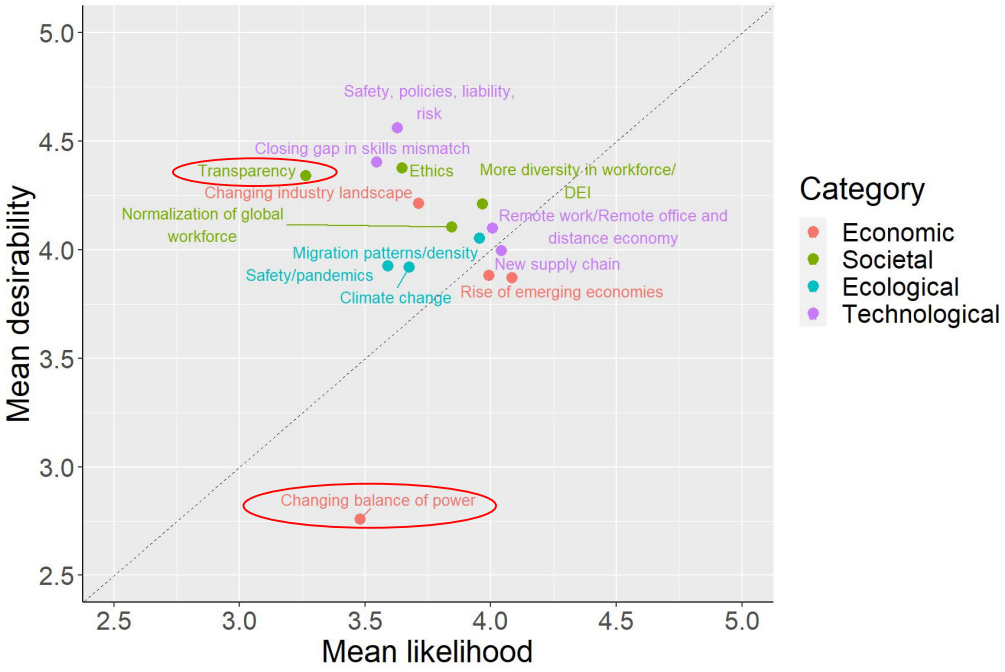

Figure 3. Feedback on Factors, Desirability vs Likelihood

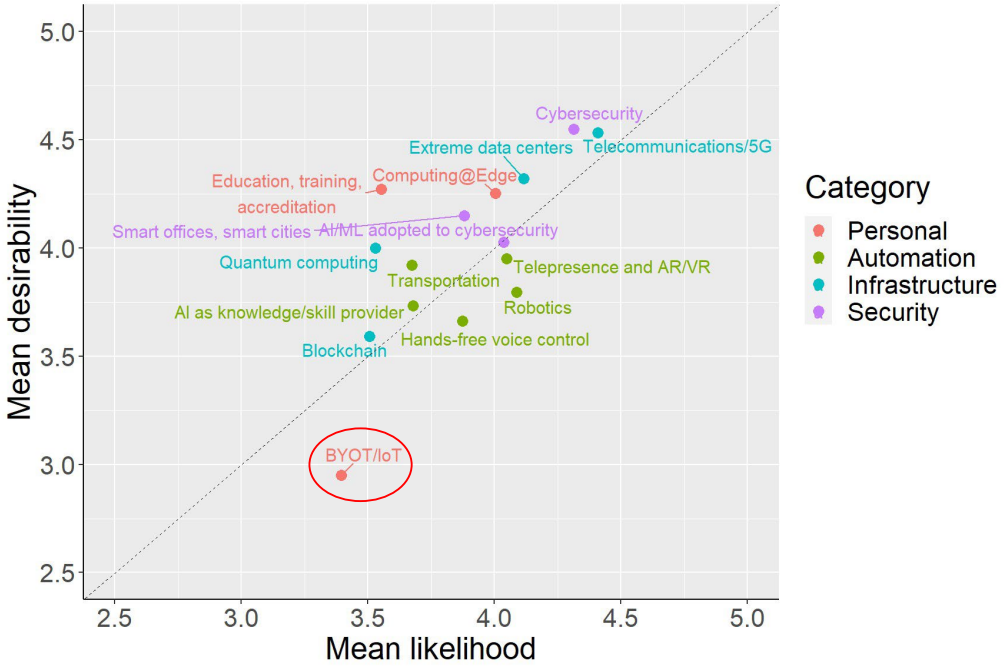

Figure 4. Feedback on Technologies, Desirability vs. Likelihood

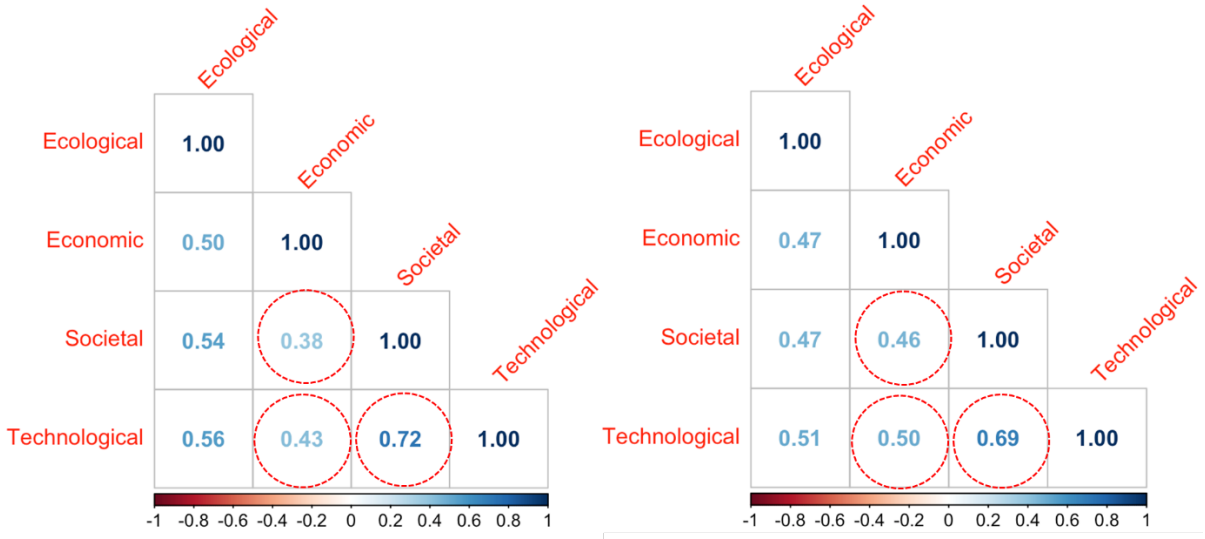

Figure 5. Factors Correlation, Likelihood (left) and Desirability (right)

The gender, geographical, age, professional, etc., distribution information of the respondents could be found in detailed FoW Report [1], including these graphs here is beyond the scope of this paper.

Overall Insights

Insights gained from our series of panel discussions with leaders from industry, academia and the government are compiled to share recommendations and learnings. We have observed some relatively obvious insights, such as:

- The future of the Workforce will be hybrid; while some workforces will continue to be onsite, others will continue remotely, and some a combination of the two. The pandemic was a forcing function that revealed to a large audience that a significant amount of work could be done without employees being physically present in an office. However, for a variety of reasons many people would prefer a hybrid between 100% work from office and 100% work from home.
- Technology kept up. Current technologies are sufficient to enable a large percentage of information workers to work remotely. Security was adjusted to account for the workforce working from home. Moving many employees to remote work exposed security issues (pre-existing in many cases), but not necessarily new issues. Remote presence using a variety of tools demonstrated that many meetings can equally effectively be conducted virtually.
- Technologies, like those that enable metaverse (virtual worlds), will make working remotely closer to face to face, office work. They will also improve oversight of employees because the Metaverse will include a spectrum of social, economic, and ecological enablers and make them more effective and efficient than in person [8]. For example, avatars can use whiteboards to draw, interaction cues are present, virtual artifacts can be created that may not be even available in physical world, etc.

Surprising insights:

- Support for a holistic approach emphasized by everyone. Industry, governments, academia, and professional organizations are forced to work closely together for optimal outcomes. Similarly, the problems addressed are a complex interplay of technological, economic, social, and ecological aspects. It is difficult to look at any one in isolation.
- Developed and less developed countries have incurred similar problems with remote work, primarily due to the lack of broadband and Internet access in vast and underpopulated areas.
- Only a small percentage of academia was ready for remote teaching and an even smaller percentage was ready for fast-paced advancement of technology to keep up. Most schools and universities weren't ready to deliver education online. We also propose that the curricula/courses/degrees are designed for the way we will work in the future rather than the way we used to work. The education system needs to be a step ahead of the way things will be rather than a step behind.
- A similar comment can be made about many commercial organizations. There was a lot of Fear, Uncertainty, Doubt (FUD) around remote work forces prior to the pandemic. The pandemic helped dispel a lot of the FUD. At least some part of the desire for hybrid work now is by people who weren't/aren't set up with a proper work environment at home. Some won't be able to

(e.g., live in a small apartment and simply don't have the space). Taking ecological and social factors into consideration, a hybrid approach is likely the best as well.

- Similar to a comment made about academia, governments need to be more forward looking. In particular, make investments that will benefit their constituents in the future, e.g., install or enable the installation of high speed internet in their areas, or incentivize the creation of office space when none exists for people to conduct their information jobs outside the home, when there is no company office in the vicinity. Regulations may also need to be updated to enable certain things to happen. In some cases, government may not need to actually build high speed Internet infrastructure or shared office space, but may need to assist constituents to be able to afford such things until they've established themselves via a new job that they previously couldn't have applied to.
- Legislatures are still not sufficiently prepared for evolving labor markets and associated taxes for local and remote workers who report across geographical boundaries. Nor are governments understanding investments they are making in schools for the workforce that might be working for other countries.
- Somewhat counterintuitive to us was that some technology accelerated development under COVID constraints (e.g., telepresence, AR/VR), others slowed down (e.g. Smart Cities, Extreme Data Centers), while some continued at the expected pace (e.g. robotics, AI at edge). All of them followed the Gartner curve, which was either accelerated, flattened, or remained in the same shape (see Figure 6).

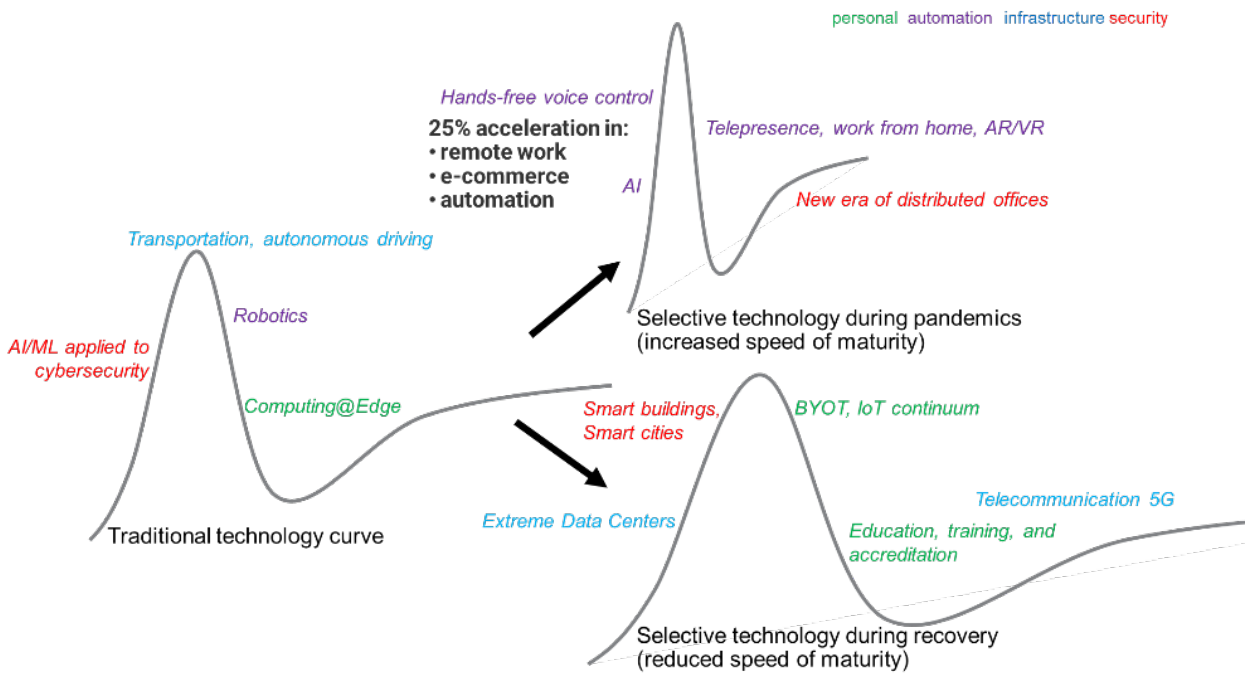

Figure 6. Technology Curves Under Pandemics

Summary, Recommendations, and Outlook

After a full year of holding virtual panels around the world, we were surprised how many similarities but also differences each region's participants perceived on the FoW. Our intent all along was to turn these

insights into recommendations to those who can act upon them. Our strong conviction is that FoW is not in the hands of a single group of people, but rather a common goal and responsibility of industry, academia, governments, and professional organizations.

Equally, it is also the responsibility of each individual to take their own future seriously, to equip themselves with the required IT support if working in hybrid/remote mode. Even more importantly, individuals should equip themselves with the required knowledge to be current in the ever-fast pace of technology evolution.

We trust that FoW is going in a direction to all stakeholders. The pandemic was a wake-up call that help us address urgent problems but also realize fundamental shortcomings of the workforce. Globally, all nations and technologically all domains are addressing the problems and making work more effective, efficient and equitable for the next generations to come. We conclude the paper with the recommendations below.

If we were to repeat this effort, we would add geopolitics to the factors, it could be very impactful to many aspects of future workforce, especially the overall wellbeing of employee. Resignation and employee metal health in recent years since the pandemic is another topic we would emphasize for the future workforce. Similarly, we would address more technologies, with energy management (generation, transfer, storage, battery lifetime, etc.) being a gap in our current analysis.

Table 3. Recommendations Summary from Panels Held

Industry	It is all about people! Hire those who can adapt! The best people attract the best people!
	Office/home have advantages/drawbacks for different career stages; go hybrid
	Early career employees and new tech – attractor for hiring
	Companies have a duty to give back to communities
government	Properly balance labor markets
	Look holistically at technology & society
	Take advantage of remote work for geo-depressed areas
	Enable reliable, high-speed communications infrastructure for hybrid work environments
	Establish sustainable Workforce in a well-balanced labor system
academia	Enable people to re-invent themselves multiple times throughout their career
	Retrain for new tech., e.g., AI, reskill, upskill, vocational; adapt curricula to future needs
	Changing demand for skills: interdisciplinary, global:
	Perpetual education! Learning never ends; train to learn how to learn; prepare for industry
Professional organizations	Redefine concepts, define hybrid careers, assist individuals and corporations
	Derive principles, best practices for trust, transparency, accountability, policies
	Leverage power of convening, educate legislators, technology predictions & roadmaps
	Organize community responses to the issues of safety, security, and privacy when exploiting AI & Robotics; collaborate with legislators, international bodies
	Redefine concepts, define hybrid careers, assist individuals and corporations

Acknowledgements

We would like to thank our 1480 survey respondents, the approximately 200 participants of the panels around the world, as well as approximately 50 local organizers. The IEEE Industry Engagement

Committee and in particular Patrick Russoniello helped us throughout the process. Mike Wehrman helped with conducting the survey. We also thank the IEEE Computer Society for publishing the longer report.

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AUTHORS

MARTIN ARLITT is a principal research scientist and research team manager at Micro Focus. His research interests include workload characterization and performance evaluation of computer systems and analyzing network traffic to improve IT security. Contact him at martin.arlitt@microfocus.com.

PAOLO FARABOSCHI is a fellow at Hewlett Packard Labs. His research interests include the intersection of architecture and software. Faraboschi received a PhD from the University of Genoa, Italy. Contact him at paolo.faraboschi@hpe.com.

THOMAS COUGHLIN is President of Coughlin Associates. His research interests are in digital storage and memory and their applications and is a long time IEEE volunteer. More on Tom at https://tomcoughlin.com and you can contact him at: tom@tomcoughlin.com.

EITAN FRACHTENBERG is a visiting associate professor of computer science at Reed College in Portland, Oregon. His research interests include performance evaluation and optimization, computer systems, and the intersection between technology and society. Contact him at eitan@reed.edu.

PHIL LAPLANTE is a professor at Pennsylvania State University, State College, Pennsylvania, 16801, USA. His research interests include AI/ML, computer and systems security, and safety critical systems. Contact him at plaplante@psu.edu.

DEJAN MILOJICIC is a distinguished technologist at Hewlett Packard Labs. His research interests include OSes, high performance computing, distributed systems, and systems management. Milojicic received a PhD from University of Kaiserslautern. Contact him at dejan.milojicic@hpe.com.

NITA PATEL is Senior Director of Engineering Lead Design Center – Farmington at Otis. Her research interests include product capabilities in connected, smart, IoT-based platforms. Patel received her MS Computer Engineering from Southern Methodist University in Dallas. Reach her at nita.patel@ieee.org.

ROBERTO SARACCO is the IEEE 2022 New Initiatives Committee Chair and co-Chair of the Digital Reality Initiative. His research interests are in the areas of Digital Transformation, Digital Twins and Artificial Intelligence. Contact him at roberto.saracco@gmail.com.