2019 was quite a year, 2020 will be even greater

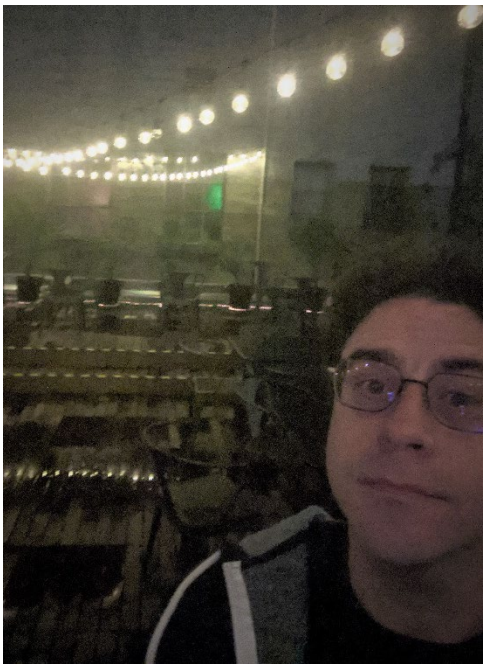
Our annual Janus-like summary and forecast

We asked all of our folks and several of our friends what they thought were the most significant things of 2019, and what they thought 2020 would bring us. Here is a compilation of their thoughts and vision.

Alex Handy, Museum of Art and Digital Entertainment

Stealing stuff

Summing up the year in technology advances is one thing, but I tend to look backwards during a year. In that regard, Frank Cifaldi probably had the busiest year with his Video Game History Foundation. He works tirelessly to save documents, lost games, and historical remnants of this industry we're all so fascinated by. To that end, he spent time in *Game Informer's* archives this year, and is evidently actively scanning things. I suppose my highlight was the fact that someone is doing this work now, as it fills a giant memory leak our industry had failed to plug for years.



Frank's advice to the industry is: steal from work. Take home concept art, source code, models, etc. Save them. Most companies won't preserve this stuff over time. So, unless people take their work home with them, much of the history of this industry could be relegated to word of mouth only. Don't let the backup tapes of old go in the dumpster. Save them.

That type of archival work is actually just the day to day work for Jason Scott at Archive.org, where he has pushed teams to not only save everything they can, online and offline, but he has also driven entire development projects around porting the MESS and DOSbox projects to JavaScript. Thus, if you go to https://archive.org/details/softwarelibrary_msdos_games, you can not only play these old PC gems in your browser, but if you sort by date added, you can see just how often new games arrive.

Elsewhere, Jason has archived software across many machines and continues to upload treasures like old PC magazine cover mount discs and driver CDs: https://archive.org/search.php?query=mediatype:software&sort=-publicdate

By comparison, we here at the Museum of Art and Digital Entertainment, https://themade.org, have been far less prolific. We've continued to host our library of over 12,000 playable games across 40+ systems to the public. As a physical window into how games are made, and the history of this industry to the public, we're not able to spend as much time archiving digitally online, so we're very happy to see this work is finally being performed at a steady, and frankly, amazing pace.

Alex Handy is the founder and director of the Museum of Art and Digital Entertainment, and works at Red Hat by day. The MADE was founded in 2011 as the world's only all playable video game museum. The museum, located in downtown Oakland, hosts playable exhibits of significant works. In 2016, The MADE relaunched the first MMO, Habitat, at neohabitat.org.

Alex Herrera, The journey to ubiquitous ray tracing hits a tipping point with the introduction of Nvidia RTX

Workstations and ray tracing

Early in 2019, I reviewed the first Quadro built on Turing generation silicon with RTX—a product and technology that specifically focused the bulk of its technological advancements on accelerating ray tracing, rather than simply adhering to the historical path of leveraging more transistors to boost conventional 3D graphics. I came away with observations and thoughts chosen specifically in response to the early criticisms of analysts and game enthusiasts that were not blown away by the performance of Turing RTX on conventional 3D graphics over previous generation Pascal.

To make the transition to ray tracing will not only take quite a bit of time, it will mean having to break the chicken-and-egg dilemma software and content developers face: why spend a lot of time or money on ray tracing when the installed base of hardware isn't very good at it yet? That's where the long-term value of Turing and Quadro RTX lies, to help break that Catch-22 and help kickstart a mass-market transition. The transition has to begin somewhere, and this looks a viable time to start.

Looking back years from now, chances are the criticism and Turing's more mundane improvements in legacy 3D graphics will be forgotten. And it's altogether possible we'll judge the Turing family's introduction of RTX as the linchpin that started the transition to the era of ubiquitous ray tracing. And if that's true, then Nvidia will be more than happy to have weathered some short-term discomfort to have pioneered that shift.

While I've often had to revise past statements to align to a differently evolved reality, these are looking safe to stick with as the year comes to a close. Nvidia's building momentum for ray tracing quickly in both gaming and professional applications, and the RTX suffix Quadro (at least) boards are dominating the market in their respective price points.

That's of course not to say ubiquitous ray tracing is here. To emphasize, the transition won't be overnight. But at the tail end of 2019, it certainly seems like we've hit the tipping point, and now it's just a matter of when, not if. That's because—with the exception of performance and cost—ray tracing is virtually always the preferred rendering technique. And history has shown time and again, if performance and cost are the only stumbling blocks to a path that is overwhelmingly preferred, then it's just a matter of time before the industry's incessant gains in performance and reductions in cost resolve the issue, allowing the ecosystem to gradually adapt and transition. With RTX entering the scene in 2019, Nvidia kicked more than a few of those stumbling blocks out of the way.

The workstation market performed well beyond even my most bullish expectations

As the analyst and author behind JPR's Workstation Report series, I'm responsible for not only tracking the workstation and professional GPU markets, but forecasting out as well. Given opinions and insights into the market, as well as overriding global economic conditions, I have been coming out in recent quarters with growth in the upper single digits to 10% or so. Now bear in mind these are numbers I've been told by (for example) wall street types were far too exuberant, given the market's familial ties to the broader PC markets which again, have been stagnant to contracting to barely growing.

Well it turns out, not only was I not overly exuberant, I wasn't exuberant enough. So far over the first three quarters of 2019, the year-over-year workstation market growth figures came in at 18.3%, 18.1%, and most recently 21.3%, respectively. The numbers have been so strong that given Q4's likely results, 2019 will not only crush my forecast for 2019 but most likely hit my currently predicted number for 2021. Then go ahead and compare those 18%+ numbers to the tepid 1.1% growth in WW PCs that Gartner reported for Q3'19 (and bear in mind, given the PC market's recent flat-to-contracting trend over recent, that 1.1% was not at all a disappointment but rather a very welcome number).

The reason the workstation market's both predicted and actual growth significantly outpaced broader PC markets is the same: There is a fundamentally different dynamic in place within the workstation market than mainstream PC computing. Vendors are justifiably more confident to hang their hats on the workstation market than most other PC-related markets, as the workstation does not suffer from the forces that have been dragging down the PC market as of late. Those forces include lagging replacement cycles due to reaching "good enough" computing levels for mainstream corporate and consumer usage, as well as some users ditching the PC altogether in favor of alternative digital devices like smartphones. The workstation market, for good reason, is affected by neither force and, as such, has been enjoying a ride on a very different trendline than its sibling PC-related markets.

Senior Analyst Alex Herrera has, for the past 30 years, been involved in the architecture, engineering, and marketing of 3D graphics, video, and microprocessor chips. At Jon Peddie Research, Alex's focus is fixed on the markets, technologies, and products related to computer graphics and professional client computing. Alex authors JPR's Workstation Report and writes for TechWatch, and as a consultant continues to advise companies competing in the graphics and semiconductor businesses.

Andy Marken, 5G gets serious … honest

The tip of 5G finally arrived

How fast is 5G? It takes 45 minutes to download an HD movie with 3G. 4G requires 21 seconds.

It takes longer to read this sentence with 5G than to download the movie. And that's a big reason AT&T, Verizon, Deutsche Telekom, Vodafone, Telefónica, Orange, Telmex, Telstra, China Mobile, China Telecom, NTT, Skytel, Unitel, MTS, SK Telecom, and well, everyone is pushing to build out their 5G networks (terrestrial, wireless, satellite). 5G is vital to tomorrow's business/commerce because, by 2025, almost everyone and everything in the world will be wirelessly connected.

All of the carriers have to do is build out their infrastructure with more cell towers, small cells and distributed antenna systems (DAS)—which requires time and money.

Source – Qualcomm

Qualcomm, Ericsson, Nokia, Huawei, and others have been busy for the past five years pushing their hardware/software, saying it's "almost here."

Countries field testing or researching 5G

Field testing Researching

Mobile network evolution

Year	Generation	Maximum data speed**	Data transfer per second**	Time to download full HD movie***
1979	1G	**none (voice only)**	n/a	**n/a**
1991	2G	**14.4 Kbps**	1.8K	**Over a month**
2000	2.5G	**53.6 Kbps**	6.7K	**Over a week**
2001	3G	**384 Kbps**	48K	**Over a day**
2010	4G	**100 Mbps**	12.5MB	**7 minutes**
2020	5G	**1 Gbps**	125MB	**40 seconds**

** 1 exabyte = 1 billion gigabytes* *** Theoretically possible* **** 5GB file size*

Sources – Wired, 5G, Qorvo, ECU

In 2019, the tip of 5G finally arrived with Qualcomm unveiling its Snapdragon chips while they, Ericsson, Huawei, and others unveiled—and began—infrastructure tests.

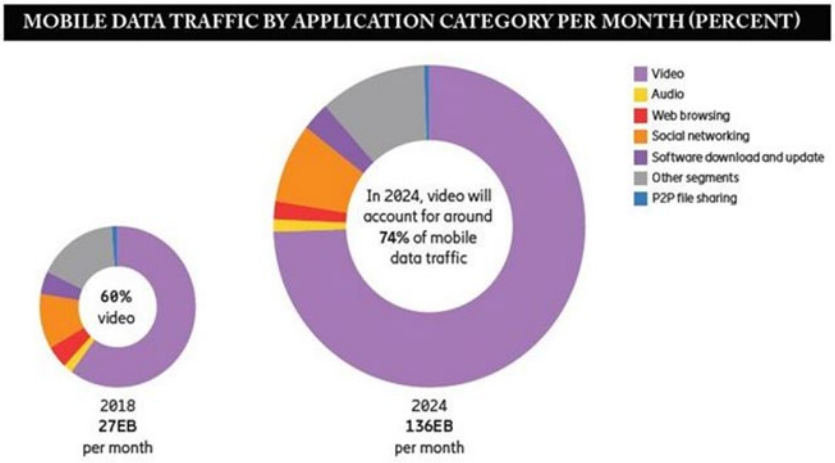
With the world's growing dependence on connectivity/data everywhere (on the road, in buildings, everywhere), in two years:

- 3% of global mobile devices/connections will be 5G-capable.
- There will be nearly 549 million public Wi-Fi hotspots.
- 22% of global Internet traffic will be mobile.
- 80% of data traffic will be video.

By 2024:

- 4.75 billion 4G smartphones will be in use, 2 billion 5G.
- mobile data traffic will increase by a factor of 5.
- 25% of traffic will be carried on 5G networks.

The driving force for wireless/wired service providers will be mobile streaming video.



Source – Ericsson

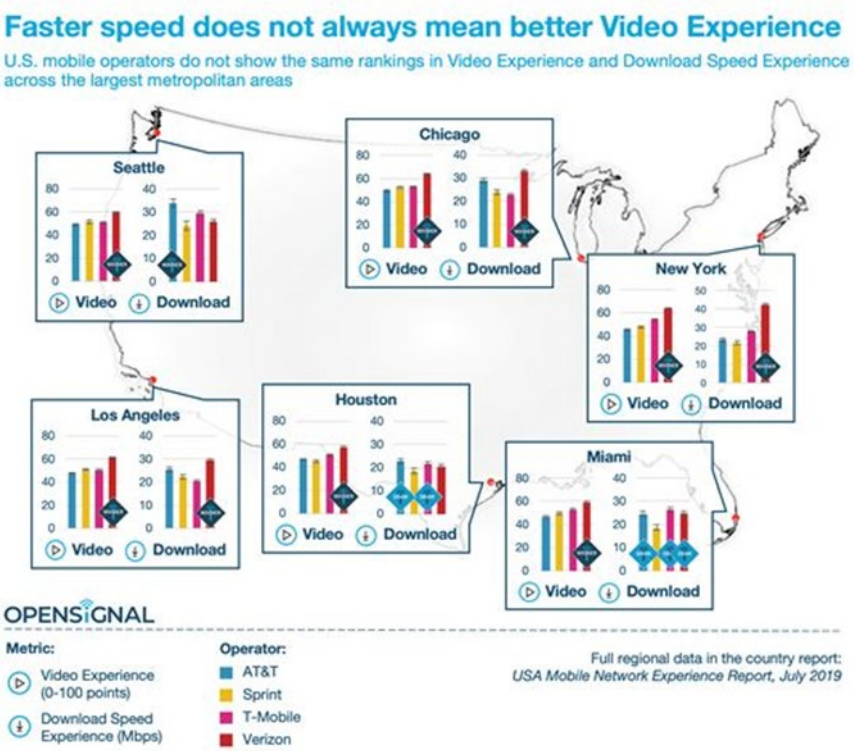
The demand is being driven by people in emerging countries who can usually only afford one screen as well as Gen Z/Gen Alpha folks who have never known life without a screen in their hands.

Source – familyeducation

IHS Markit Digital Orbit found that 78% of US consumers will upgrade to 5G for their wireless smartphone usage and home-networking needs. The reason was consistent for video streaming.

To stimulate upgrade (more expensive) to 5G smartphones and expanded unlimited data programs, all of the US providers are offering free one-year video programs to new customers: Smartphone sales are finally growing again by 15% instead of shrinking, according to IDC and Gartner. T-Mobile broke the ice by bundling a year's worth of Netflix free to new customers. Sprint followed suit with a year's free Hulu.

AT&T desperately needs subscriber additions, so expect them to offer up content from their expensive ($180.4 billion debt) Times Warner/HBO bundle. Verizon leveraged its relationship with Disney to offer Disney + free to new customers and you can expect Vodafone (a major Verizon investor with presence in 90 countries) is discussing a similar promotion.



What most consumers don't realize is that current 4G wireless services already provide enough performance to support most types of video content streaming.

As 4K UHD content begins dominating the scene, two-thirds (62%) of homeowners indicate they will replace home internet fiber with 5G Wi-Fi service. In addition, 5G will be vital for live video such as sports and live entertainment events as well as video game play (47% of Gen Zs) and AR/VR activities (35% of Gen Z/millennials). According to OpenSignal's State of Mobile Video Experience report, 37% of the 100 countries enjoy Very Good or Excellent mobile video … *now*.

While Singapore is routinely at the top along with South Korea, and the top 11 are in Europe; the US is ranked down in the Fair category. Full 5G deployment (small cells, mmWave) in the US alone is estimated to cost as much as $275 billion over the next seven years and similar levels of investment are expected in the other 194 countries around the globe. If the spectrum remains tight and consumer demand for mobile video continues to increase, we will see data service costs rise or an increase in streaming management (throttling/lowering video quality).

Source –reddit.com

Neither solution will satisfy regulatory agencies or … consumers!

Andy Marken is an author of more than 400 articles on management, marketing, communications, industry trends in media & entertainment, consumer electronics, software and applications. Broad range of technical and industry expertise especially in storage, storage

management and film/video production fields. Extended range of business, industry trade press, online media, and industry analysts/consultants.

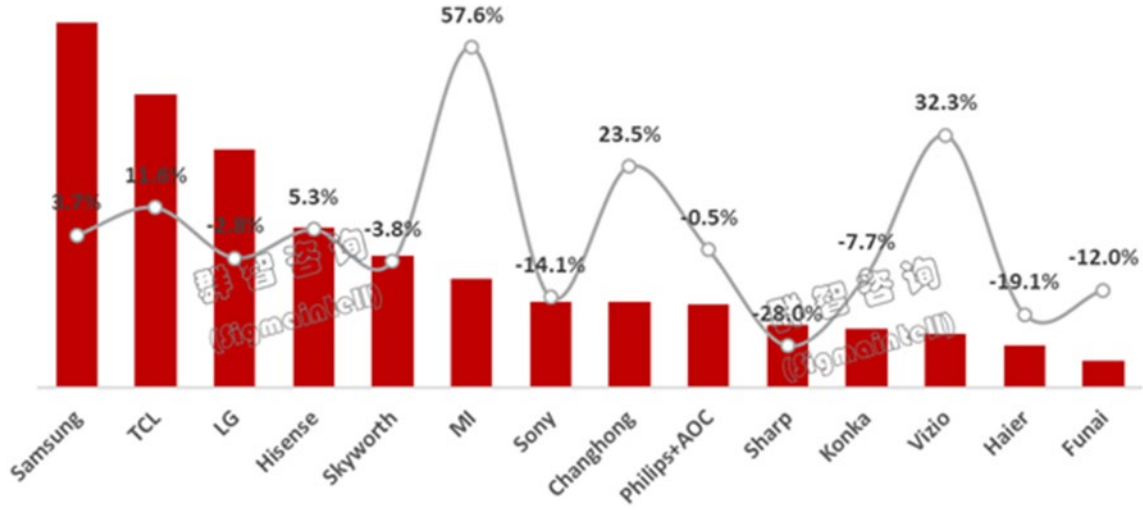
Bob Raikes, The display industry tanker turns

LCDs slowly give way to OLEDs

This year has been something of a turning point in the display industry. However, the momentum of the industry is now so weighty that the changes have been foreseen for several years.

The big news was that Samsung announced that it would abandon LCD production altogether by 2025. The writing has been on the wall for this move for several years.

Because of the size of its domestic market, the Chinese TV makers are on their way to totally dominating the volume—Sigmaintell has TCL at second in the market now. It means that, a few years ago, imports of LCDs for TV manufacture from Korea and Taiwan had become a high value item in Chinese imports. The government decided that it wanted to capture that value in its own economy, so started a project to finance panel making in China. This gave access to low cost (or free) capital available to Chinese panel makers such as BOE and CSOT.



TV Data from Sigmaintell for Q3 2019

In an industry that is so capital intensive, access to free or low-cost capital is a killer advantage. As a result, it no longer made sense for those without access to this capital to invest in LCD production as they would be very unlikely to ever make a return on investment.

Given that TV panels are more than 50% of the LCD market, winning in that market means winning the overall market which includes IT panels for notebooks and monitors and even some low-end smartphones.

Samsung started to reduce its LCD production volume a couple of years ago, but this year, with the oversupply of LCD caused by big new LCD fabs in China, it closed down its last large LCD fab in Korea to convert it to develop production of a new display technology—QD OLED. This uses an architecture like an OLED, but the OLED material only emits blue light. The technology uses patterned quantum dots to convert that light to red and green. It will take a couple of years to come to any kind of volume, but it should provide fantastic image quality with fewer lifetime and burn-in problems than LG's OLED technology.

Like Samsung, LG Display has been moving away from LCD to its large area OLED technology, but continues to plan more capacity for its large OLED technology.

Flexible OLEDs

Flexible OLEDs have taken over the premium end of the smartphone market, but almost all of them appear to be rigid because they are protected by glass. Samsung and other display makers have been showing fold up and roll up smartphone concepts for five or six years, privately, but 2019 finally saw the first tentative steps to introduce production products based on the concept. Although the displays have been makeable for some years, there was a challenge in getting the display to have a tight bend radius and in preventing accidental damage. The problems of Samsung's Fold smartphone introduction have really highlighted these challenges. The expectation for next year is that the next generation may use ultra-thin glass rather than polymers for protection in an attempt to make them more robust.

In 2020, you can expect to see lots of new attempts to find a winning form factor for these foldable devices. Personally, I'm looking for a tri-fold device that will open out to a tablet size, but that takes a while to get slim enough to go easily in a pocket. Flexible OLED will also get a boost because the displays are so thin. Using them means that the smartphone designer will have more space for the bigger 5G radios needed in the next year or two.

There is lots of interest in microLED and miniLED. MicroLED displays are still not in the market, but it won't be long before something comes to market—possibly in 2020. The technology has huge promise and there are dozens of companies working on it, including all the major display makers. It should be able to provide great color, wide viewing angles, and high speed with high energy efficiency and long life. What's not to like?

The challenge, though, is in manufacturing in high volume at low cost. There are some clever ideas to make this work, but nobody can do it yet, so you might see microLED displays in products in 2020, but they are likely to be small, lowish resolution devices that need very good energy efficiency, so think of premium wearables.

In big LEDs, you will see more and more stadium sized and smaller displays, but they remain tricky and expensive to make and there is no 'Moore's Law' breakthrough coming that will radically change the costs in the next couple of years, so the story will be evolution, not revolution, unless somebody can solve the production problems of microLED. If you have seen Sony's Crystal LED (Cledis) display at trade shows, you'll understand the promise of the performance, but while the cost of a big UltraHD display remains in the millions, the product will be niche.

You can also expect to see some more cinemas moving to LED, but only handfuls in any one country, at the most, in the next year. The technology has moved out of just Korea and the US and is now in India, Malaysia and some European countries. This year, Sony has said that it will supply its Crystal Display technology for cinemas, but, again, cost will be a barrier to wide adoption.

Turning to IT displays, I was slightly surprised to see OLED making a small comeback in notebooks. Notebook makers introduced OLED notebooks back in 2017, but ran into problems with supply, so they were usually out of stock. As a result, they stopped, but Samsung was promoting its technology again this year, and got some design wins, but didn't get much market share.

Monitors continue to develop incrementally. Taiwanese LCD and monitor makers are very keen on using miniLEDs in their backlights to give high brightness and HDR performance, but there will be challenges with cost for this. It's also not clear that outside gaming and content creation, there is much need for more brightness or contrast than is currently available for most office applications (although it always looks good and that might be enough!).

AR and VR have moved along, somewhat. The very high resolution large VR displays that are really needed for VR are not yet available—and may be very expensive when they do get here. For now, the product that has impressed me most is the new Varjo headset that has a high resolution display for the foveal region of the eye to give great detail. It also has very fast processing of camera images to make a very compelling mixed reality impression. VR in general has had a tough year, with low volumes meaning impressive products such as the StarVR (launched at Siggraph in 2018) have effectively been abandoned. Even Magic Leap, which seemed to have an amazing ability to raise money, has had to lay off staff after selling just 6,000 headsets in its first six months of sales, against a first year target of 100,000.

As well as being publisher, managing editor of (and a writer for!) Large Display Monitor, Mobile Display Monitor, and Display Daily, Bob Raikes was for several years the displays editor for The Peddie Report and a regular contributor to Computer Shopper and other titles including the SID Information Display magazine. He has appeared on TV and radio, including BBC World and BBC Radio 4. He is a regular speaker and keynote speaker at industry and corporate events, and an avid long-distance bike rider.

Carol Warren, What's next for eWaste?

A circular product cycle needed

2019 has been another year of incredible progress in technology with advances in quantum computing, 5G, digital healthcare, autonomous vehicles and a host of other remarkable breakthroughs. But what did 2019 leave as a legacy? A mountain of e-waste.

Thanks to a bevy of energy-hungry data centers and several Loon balloons,

half of all global households have internet access, and 5.13 billion people own mobile devices. The IoT and edge computing have had their impact too. Now sensors and specialized processors are added to products that never before had them, creating wearables, smart buildings, smartphones, smart TVs and more. The 2020 decade will see millions of consumers trade in their 4G phone for 5G, where will this e-waste go?

2019 intensified the focus on developing and training various forms of Artificial Intelligence (AI), to add to the technology mix and quickly found that it takes an enormous amount of energy to train AI. A recent MIT Technology Review article said new estimates suggest "Training a single AI model can emit as much carbon as five cars in their lifetimes."

There is a good green side to AI, it's quietly revolutionizing the efficiencies of how we produce, transmit, and consume energy. AI is also helping us to find cleaner, more sustainable sources of energy production.

So, where does all this lovely hardware go when its useful day is over? The United Nations calls this fast-growing waste stream "a tsunami of e-waste."

In 2018, the world's population discarded 50 million tons of e-waste. By 2021, e-waste will grow to more than 60 million tons. Although nearly 100% of e-waste is recyclable, the current 15–20% e-waste recycling rate is not enough and the remaining 80% that has lead and other toxic materials that are going into our landfills.

There is a business case to be made in e-waste recycling that would fulfill our urgent need. A recent EPA report revealed that by recycling 1 million cell phones, we can recover more than 20,000 pounds of copper, 550 pounds of silver, 50 pounds of gold and 20 pounds of palladium. For those not familiar with palladium, it's a precious metal used for making electrical contacts. One ton of circuit boards contains about 40 to 800 times more gold than one metric ton of ore. There is 30 to 40 times more copper in a ton of circuit

boards that can be mined from one metric ton of ore. And rare earth metals are becoming rarer.

To develop a sustainable e-waste solution, we must adopt a circular product cycle of produce less to pollute less, then recycle—and find a way to do that without lowering our quality of life. So, if we reduce, reuse, and recycle, then Mother Nature can join in with all of us and look forward to the next disruptive technology that will emerge out of a research lab in 2020.

Carol Warren is responsible for the management, strategic development, and tactical supervision of technology accounts ranging from Clean Tech to consumer electronics to semiconductors. Warren and CREW co-founder Bob Eminian have managed extensive national and international marketing communications programs for global technology giants to nimble, innovative start-ups. Through Warren's long involvement in the technology marketplace, she has learned the importance of telling each clients' own unique story and integrating digital media opportunities into the marketing mix. She has a bachelor's degree from California State University Long Beach and is a board member for several local charities and organizations.

Jon Peddie, Looking back and forward

2019 in review and guess at what's coming

It's that time of year when we pause, take a breath and say, whoa, the year's over? What happened? Where are we headed? As the above image portrays, it's a lot clearer looking back than forward.

2019 was the year ray tracing entered the mainstream. Nvidia kicked things off in late 2018, but it was 2019 when the new ray traced games started to arrive. Not only new games, but older games were also jazzed up with retro-lighting and shading software from unaffiliated independent developers that ran on any GPU. Several companies introduced ray tracing benchmarks in games, game engine, professional graphics, and general purpose benchmarking programs, and two great books on ray tracing came out (Ray Tracing: A Tool for All and Ray Tracing Gems). However, the jury is still out about whether ray tracing is compelling enough for gamers to pay extra money for it. If it comes for free as it seems it will, then it will be like the transition from monochrome to color.

It was the year of frustration for Intel as it struggled to get its 10-nm process yields to a point that satisfied both the company and its customers. That hiccup opened the door for AMD who just happened to have a powerful new line up of 7-nm processors. It also created a pent-up demand that saw a jump in sales of PCs in Q3 prompting us and the rest of the industry to cautiously predict that the PC market's decline had finally hit bottom and was turning around.

2019 saw the expansion of GPU suppliers to 13 with several new designs from the incumbents. The combination of original design chip manufacturers like AMD, Apple, Intel, Nvidia, Qualcomm, and Chinese newcomer Jinjia were joined by two new soft GPU designers (targeting RISC-V) increasing the population of IP-GPU providers to seven. Arm, DMP, Imagination, Think Silicon, and VeriSilicon had the Libre RISC-V 3D GPU and start-up RISC-V graphics joined their ranks.

Big chips. We thought Nvidia's gigantic 750 mm^2, 18.6 billion transistor Turing chip was a monster, but it was a puny compared to the Cerebras wafer scale engine at 46,225 mm^2, and 1.2 trillion transistors, 400,000 core, and 18 gigabytes of on-chip memory.

Ultra-wide monitors from Dell, HP, Lenovo, and others went into full production and although the initial price is more than two monitors of the same size and resolution, the borderless, slightly curved displays are a dream to use for business or gaming. Stacking one on top of the other is the ultimate in multi-monitor configurations and proves the more you can see, the more you can do.

Looking ahead

2020 will be exciting and full of challenge. The trade war continues to disrupt and distort forecasts, production plans and supply chains, and burn a lot of precious time and profits trying to deal with it.

Monitors are going to get bigger in size and resolution. The growth we've already seen in ray tracing will start showing up more in content as new tools make it accessible to more users. Always on will truly arrive: CPUs will run all day on a battery that can fit in a thin and light notebook that will be almost indistinguishable from a tablet, and communications speeds for Wi-Fi, PCIe, and 5G will make things appear to happen instantly. Intel will join the ranks of discrete GPU suppliers, and Google and Amazon will expand their AI processor capabilities.

The processors will become invisible and everything will be a display—and become more interactive the closer one gets to them.

Camera sensors will continue to drop in price as they are put everywhere. Resolution and speed will go up while size comes down and your car will wear about a dozen or more of them. That will help your car find its way around without your assistance and you will go from being a liability and safety hazard to a passenger, sit up, buckle up, shut up. The decline in car ownership for people in urban areas will pick up speed in 2020.

Apple, and probably Amazon, will introduce AR glasses, while Qualcomm and Google will offer reference designs.

Everything and anything at the end of the network, the so-called edge, will not only get smarter, but it will be augmented by the cloud and managed.

More stuff will move to the cloud including gaming, security, entertainment, shopping, and medical assistance. In the cloud, vast AI systems will anticipate our needs based on massive monitoring of our behavior patterns and millions like us.

High-end, AAA, gaming trends in 2020 will have more full-screen blended motion capture (mocap) and computer graphics. A good example is *Call of Duty* and *Battlefield V*. Full 10-bit high dynamic range (HDR) color will be standard of high-end games as will ray tracing. 120 to 240 Hz 4k will also show up on many high-end games. Maps will get bigger, and games will be more open world and allow the gamer to explore and pursue side quests. Sound realism will be greater, and there will be more audio controls allowing the player to create the sound stage he or she wants. Single player or campaign modes will have fantastic enemy AI where the enemies will actually learn about you and anticipate your moves. Enemies will also become more realistic in their movement due to improved game engine mechanics and mocap. And the stories will become amazing, not limited to simply run and shoot but complex stories that you will need to pay attention to get through the game making the games emotional immersive.

Desktop displays will get larger with higher resolution, and we will spend over 90% of waking hours looking at some type of a screen on a smartphone, TV, PC, movie, driving, or shopping.

Not only will we be able to do more by seeing more, but we're going to be seeing more than we have before.

Jon Peddie is a recognized pioneer in the graphics industry, President of Jon Peddie Research and named one of the most influential analysts in the world. He lectures at numerous conferences and universities on topics pertaining to graphics technology and the emerging trends in digital media technology. Former President of Siggraph Pioneers, he serves on advisory board of several conferences, organizations, and companies, and contributes articles to numerous publications. In 2015, he was given the Life Time Achievement award from the CAAD society. Peddie has published hundreds of papers, to date, and authored and contributed to 11 books, his most recent, Ray Tracing: A tool for all.

Kathleen Maher, 2020: On track and rounding the corner to 2025

More bandwidth makes more pixels flow faster but where are the brakes?

Decade years are target years. Some of the major targets for 2020 have been ubiquitous connectivity, gender parity, income equality, and a reversal of global warming, to name a few goals we've encountered along the way. I'm for all of them.

Unfortunately, I started out first thinking about the impact of widely available, affordable, seamless connectivity, and that's as far as I got on the future topics.

The European Commission through its Broadband Europe initiative says they have achieved their goal of basic broadband for all citizens by 2013, and is headed for its next step, Next Generation Network (NGN) 100 Mbps or more for 50% of households by 2020. The goal for 5G is access for all urban areas and major roads and railways by 2025. A major goal for Europe is the establishment of a Digital Single Market.

The U.S. is struggling to get broadband to rural areas. According to the American Broadband Initiative Milestones Report the U.S. has been able to extend access to land-based broadband at speeds of 25 Mbps/3 Mbps to 92% of the U.S. Population. However, that 8% left behind represents more than 24 million people, most of whom are in rural areas.

The U.S. goals are considerably less ambitious than those of Europe. The U.S. FCC has pivoted to 5G to extend broadband to rural areas. FCC Chairman Ajit Pai says he is expanding the auctions to open up spectrum for 5G in the U.S. Notice that in all of this, there's not much discussion about affordability. In the U.S. money and competition drive innovation, not government mandates or good intentions, which means 5G has a similar timeline, but it's likely to be messy. Tom Wheeler of the Brookings Institute published a paper at the start of 2019 challenging the various companies and government bodies to get their acts together for a better rollout of 5G.

The importance of all this in our little corner of the world is obvious. More broadband connectivity will accelerate the adoption of cloud-based workflows. In 2019 we've seen every major CAD company, Autodesk, Bentley Systems, Dassault, Hexagon, Nemetschek, PTC, Siemens, Trimble, and let's throw in GIS giant ESRI declare the inevitability of cloud-based workflows. Cloud workflows will slow-roll until 5G becomes firmly established. Looking to Europe that means 2025.

Nevertheless I believe we'll start seeing the future emerge in 2020. Technology is already being built to take advantage of the seamless high speed Internet we've been promised. For example, the idea of the digital twin, living models of real-world objects are taking shape … piece by

piece, like a puzzle. Gradually sensors are being embedded in buildings, vehicles, city streets, industrial machines, pets. And, just in case you're worried about humans getting sensor implants, I wouldn't worry too much. We're voluntarily putting sensors on ourselves with connected devices, phones now, glasses next, when the time comes for a little something under the skin, it won't seem like such a big deal.

Already, companies like Trimble and Hexagon are enabling smart farms where the tractors drive themselves. And smart construction sites are on the way for 2020. Siemens and Bentley have teamed-up to digitize process and power plants even after they're built and just this week Siemens has also announced a deal to digitize shipbuilding with Navantia. As the connections get made, the pieces will come together so that the car, ship, or jet being designed today can be monitored as it's in use tomorrow.

There's nothing like the Boeing 737 cluster of disasters with its accompanying high price in lives lost as well as ongoing financial impacts on regional economies, contractor ecosystems, air travel, and stuff I don't have the time or imagination to think about right now, to underline the need for connected everything for oversight and maintenance. The technology is here. In 2020 let's see how it advances to better the way things work.

God knows, in 2019, China has showed us how it can all go wrong for the Uighurs of Zinjiang, the protesters of Hong Kong, and migrant workers. The New York Times has just published a story that demonstrates how China is making the connections that ultimately limit the freedom of a sizable chunk of the world's population.

So, now I've taken us down this path, 2020 might also go down as the year we lost control and the surveillance state took over. Scholar Shoshana Zuboff's book *The Age of Surveillance Capitalism* published in 2019 outlines the slippery slope we've already started down.

OK Boomer? How about OK Google? How about Okay Amazon? Alexa, stop watching me!

2020 has got to be the year, humans start thinking about what really happens when we're all connected. Where do we build protection, where do we open up the doors? Let's check back in 2025.

Kathleen Maher is the Vice President and co-founder of JPR, and the Editor-in-Chief of JPR's Tech Watch Report, one of the most respected insider reports published today. She is the author of several well received reports including the 3D Modeling and Animation Report, The CAD Report, and also reports on video animation, print, and audio software. She is the Editor in Chief of GraphicSpeak, a website covering graphics hardware and software, Contributing Editor for Computer Graphics World, a frequent contributor to Connect Press, and a contributor to the Handbook of Visual Display Technology (2011).

Mark Poppin, 2019 in review and what you can count on for 2020

VR and AMD rise

2019 was the year of realtime ray tracing for gaming and for graphics. Nvidia kicked it off in 2018, but ray traced games only started to trickle in this year. Expect many more ray traced games in 2020 as AMD, Intel, and the upcoming gaming consoles will also support it.

2019 was the year of AMD's complete resurgence from near-bankruptcy a few years ago. Nvidia's CEO Jensen Huang's cousin Lisa Su as AMD's CEO took on Intel with really great Ryzen products, and we also saw Intel reacting badly. Lisa Su identified that Radeon marketing was stuck in a time warp and turned over their management who were adopted by Intel along with some Radeon engineers. We wish Intel luck in 2020 as they bring out their graphics accelerators.

AMD no longer wants to be considered as a "value" company. They want to be perceived as producing premium products as noticed by positioning the RX 5500 XT 8GB directly against the faster GTX 1660 at the same pricing. However, Nvidia is nimble unlike Intel, and they are far more proactive, so AMD has its work cut out for them as Nvidia transitions to 7 nm with faster RTX graphics cards in 2020.

VR finally got some gaming love in 2019. Valve brought out a NextGen Index HMD; Oculus up/side-graded their Rift from CV-1 to S; and HTC Vive brought out the Cosmo which hasn't got a lot of love from enthusiasts. Vive has aimed for professional and industry VR, and we expect them to update the Pro, while Facebook/Oculus is banking on mass adoption at the low end of VR with standalone HMDs to track their advertising better. *Half Life Alyx*, the next update in the Half Life universe, will be the next really big 2020 VR game, and we expect Valve to put in a lot of work to make their Knuckles controllers stand out.

Generation 2.0 of VR HMDs are waiting on Nvidia and AMD to launch the next generation of video cards to move graphics and VR forward. There is some talk of multi-core modules (MCM) for 2020 although Nvidia has been working on it for over a decade. It's uncertain whether MCM will arrive in 2020, but you can bet on powerful video cards that may be more affordable.

There will likely be significant VR improvements with eye tracking and foveated rendering in 2020 that will drive more gamers to PC VR. AR will become huge beginning in 2020, and we may see some AR/VR crossover headsets. Industry has already adopted VR, but gaming still lags behind.

Politics has continued to be a mess in 2019 with expensive trade wars, weakening of long-standing international relationships, and articles of impeachment launched against the POTUS along a massive partisan divide. One should expect even more division next year as the U.S. Presidential election approaches although the U.S. economy should stay strong through 2020. We can be certain that 2020 will be a pivotal and exciting year.

Mark Poppin began his writing adventure at age 19 as a chess editor and then an investigative journalist in Dublin, Ireland in the early 1970s. Back in the USA, he became a fanatical arcade gamer who transitioned to PC gaming in 1983. Based in California, he traveled to Brazil in search of waves, moved to Hawaii in 1992 and became a Pipeline local surfer as well as surf reporter/forecaster & General Operations Director for Surf News Network Hawaii. *Mark has been a tech forum enthusiast since 1999, and became the first Video Card & Graphics mod on Anandtech forums. He became a reviewer specializing in graphics and then in VR. After retiring, he founded* AlienBabelTec*h with a team of international volunteers in 2008, and then established* BabelTechReviews *in 2014 where he continues as EiC.*

Neil Schneider, 2019: Congratulations, no cigar, have a baby

Computing HAS to change

2019 was the year computing changed, it was the year computing didn't change, and it was the year that it showed that computing HAS to change and how.

A development that really got me excited was at the Game Developers Conference in March when Google announced Stadia. All I could think about was how computing was going to change forever: the best content anywhere and on any device, inexpensive high-end computing, unlimited horsepower for developers and users alike, newfound compute ability and distribution to disenfranchised communities, a growing total addressable market, a more environmentally friendly and efficient industry…my thoughts just went on and on.

Of course, we've seen cloud gaming and realtime cloud product announcements before, but this was different because it had the backing of new broadband technologies like 5G and—let's face it—this was Google for God's sake!

It wasn't just Google. In tandem, we saw product announcements and refreshes through Sony's PlayStation Now, Nvidia's Geforce Now, Microsoft's Project xCloud, and more with more to come. All amazing stuff!

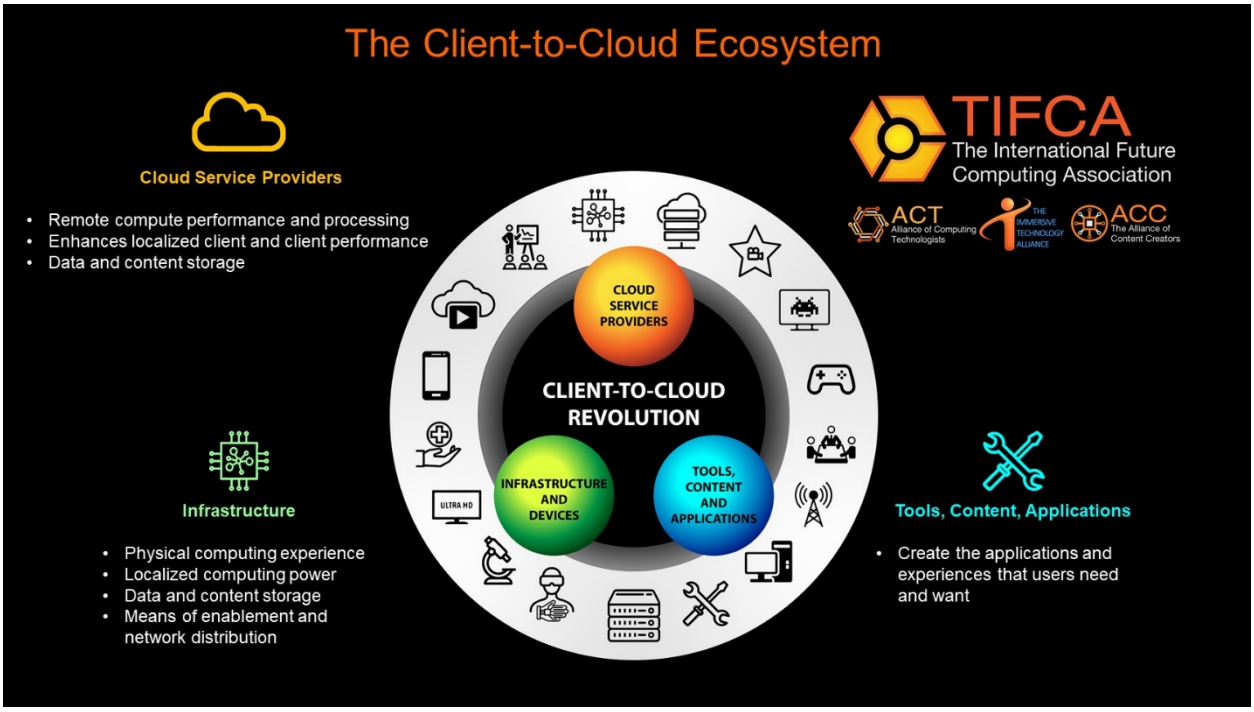
Even though gaming has been the focus and the developments have been treated as a series of product announcements, this would impact EVERYTHING and EVERYONE. Enterprise, healthcare, entertainment, education, architecture, our day to day computing lives—they would all be affected because computing was changing.

Then came my second realization of 2019: the world-changing products like those listed above only work best when there is an ecosystem to support them, and this hasn't happened yet. In the case of Google Stadia, their product reviews deservedly credit them as visionaries in this new paradigm, and while their subscription model and gaming library size are hotly debated to this day, it's their gaming latency and sheer bandwidth usage that seems just outside of Google's purview to fix on their own.

My reading shows that Sony's PlayStation Now is in a similar boat, and their solution is to allow gamers to download titles directly to their PlayStation 4. This effectively means that Sony's cloud gaming service is a commercial break for their games console, and the paradigm shift hasn't really come to its full fruition. In other words, computing hasn't changed…yet.

The third 2019 development is ongoing in The International Future Computing Association. There was realization that the use of the cloud and how the cloud is used is a choice according to where it's most effective for the compute horsepower and data to live. Instead of replacing our client devices, we should be enhancing them. Sure, if infrastructure permits, there is great merit to having "dumb terminal" devices and a great need will be met with that. AND, what if our devices could put in support so we don't need to transfer as much bandwidth and still get the amazing experiences only possible with a mix of client and cloud technologies? How can we make compute work when there is and there isn't connectivity readily available? Cloud-only technologies would equally benefit from this too.

This realization introduced a second factor. This future requires that content and application makers are able to write once, and publish to a multitude of devices, each with its own processing ability, ergonomic nature, and benefits.



The only way this truly exciting future can be realized is if the ecosystem is willing to come together and collaborate in a meaningful way, and that's going to be some journey. TIFCA has been calling this journey the Client-to-Cloud Revolution, and it requires the ecosystem involvement of the client, the cloud, and everything in-between.

To get the ball rolling, TIFCA published its Vision Document for the Client-to-Cloud Revolution in July. It also launched The International Future Computing Summit in Silicon Valley last November. Co-sponsored by Intel and Advanced Micro Devices, the summit was a unique

gathering of the client-to-cloud ecosystem. Its purpose was to deliver a snapshot of the industry as it exists today and coalesce the ecosystem to build what will exist tomorrow—the next era of computing!

L–R: Neil Schneider (TIFCA), Jon Peddie (Jon Peddie Research), Arvind Kumar (Intel), Daryl Sartain (AMD) at The International Future Computing Summit

This brings us to what I think were the most exciting moments of 2019. Check out the visionary Intel, AMD, Jon Peddie Research, and TIFCA presentations at the IFC Summit. I think it's a rarity to see competitors and pundits alike sharing the same energy and language as they did on the same stage that day.

2019 laid down a strong foundation for the ecosystem to collaboratively build what's next in future computing, and I can't wait to see what 2020 has in store. Be part of it.

Neil Schneider is the Executive Director of The International Future Computing Association (TIFCA). Originally founded as a non-profit corporation in 2009 (as The Stereoscopic 3D Gaming Alliance). The International Future Computing Association (TIFCA) is a network of member companies and institutions that each play a part in what are, and will be, the ultimate tools and experiences that impact our daily lives using computer technology and media.

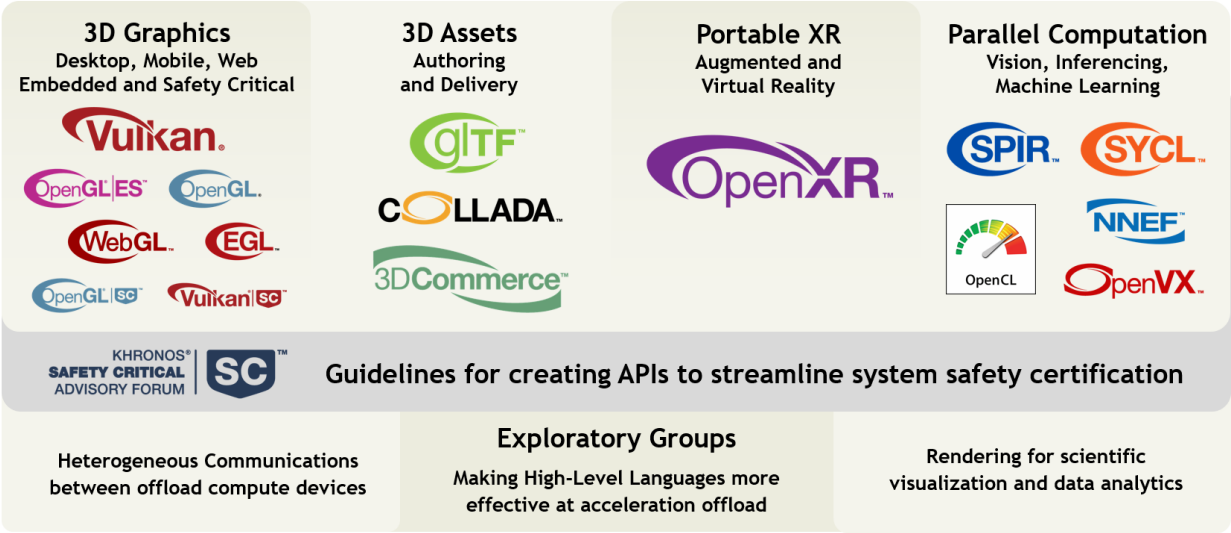
Neil Trevett, Khronos—fostering industry cooperation at every level

May the APIs be with you

Standards organizations exist to provide a safe space for competitors to cooperate for the good of all. In 2019, Khronos has seen powerful commercial incentives drawing us ever closer for sophisticated, multi-level cooperation, but also external dynamics trying to force the industry apart.

Firstly, the good news, many Khronos working groups have seen significant advances in 2019:

- glTF has become widely accepted as the equivalent of JPEG for 3D;
- Vulkan has been adopted by even more platforms—including Google's Stadia;
- OpenXR 1.0 has shipped and is beginning to deliver on the promise of AR and VR portability;
- OpenVX 1.3 has completed the transition of OpenVX from a traditional vision API to seamlessly integrating vision and inferencing;
- SYCL has been adopted as a key technology in Intel's oneAPI initiative.

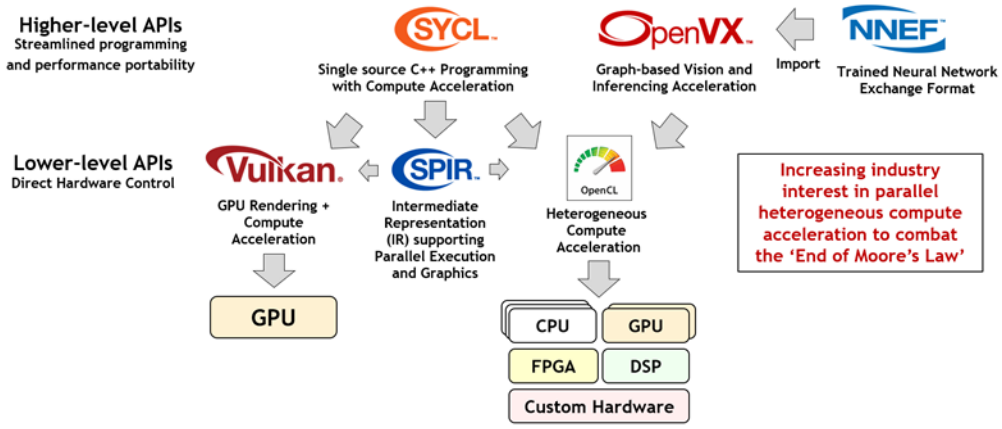


Khronos standardization initiatives in 2019

Furthermore, as tech ecosystems become ever more complex, 2019 has shown us that our standards increasingly need to be used together to solve real-world problems:

- SYCL provides C++-based heterogeneous acceleration, but relies on SPIR-V to underpin language compilation and uses OpenCL for hardware acceleration;
- XR applications can use OpenXR for run-time portability, but also need glTF for portable 3D assets to feed those applications;

- Machine learning systems need exchange formats such as NNEF to feed inferencing run-times such as OpenVX, being accelerated over APIs such as OpenCL.



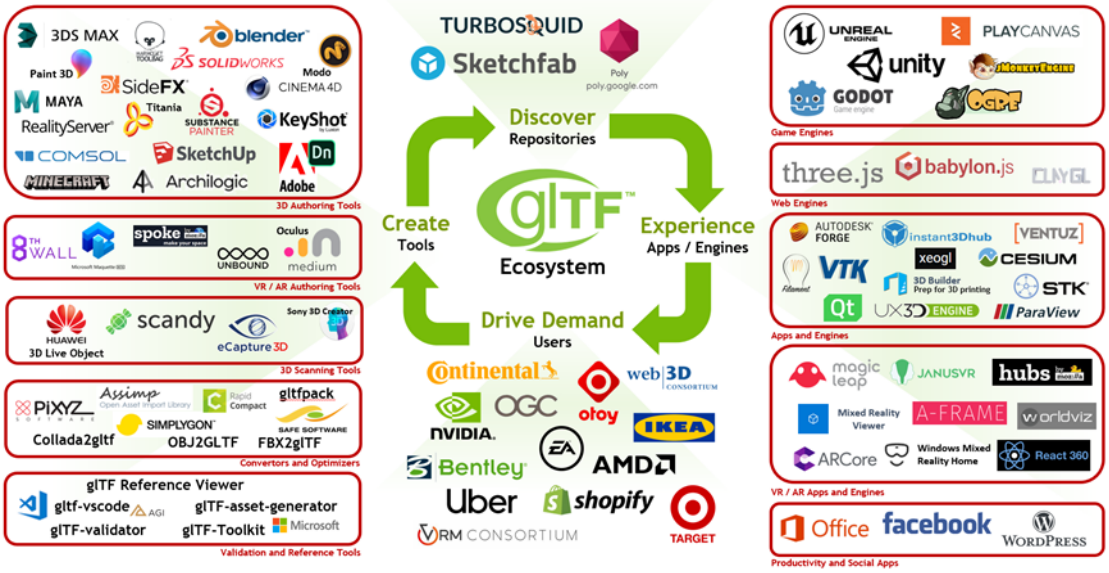
Khronos compute APIs working together

2019 has also been a milestone year for Khronos as, for the first time, user communities have joined for a seat at the table to cooperatively build solutions over our standards:

- The new 3D Commerce working group has welcomed the E-commerce community, working alongside Khronos' traditional technology company members, to leverage glTF, WebGL and OpenXR to bring 3D Commerce to industrial scale;
- The Analytic Rendering exploratory group has seen leading visualization users joining hardware and platform vendors to determine whether we can make advanced rendering technologies far more accessible to the scientific community.

Finally, 2019 has seen the ongoing advantages of cooperation encourage liaisons beyond Khronos into sister organizations as we build an industry-wide web of interconnected standards:

- OGC and Khronos are working together to enable the widespread use of 3D in geospatial applications;
- W3C is working with Khronos to build the next generation of 3D and XR in the Web and to leverage glTF as common format that all browsers can understand;
- Khronos is working with many groups inside ISO, including enabling glTF to bring widely accessible 3D to PDF files.



glTF standard for portable 3D assets demonstrating the power of a cooperative ecosystem

But at the international level, all of this cooperative progress could be overshadowed by rising forces encouraging the tech world to divide into East and West. To many of us working in the field of cooperative interoperability standards, this seems a huge backwards step from eradicating needless industry friction and inefficiencies. Khronos is committed to playing whatever role it can in leveraging open standardization to keep international cooperation alive and well.

Looking forward to 2020, Khronos is going to be busy as we gather real-world feedback on key new initiatives, approaches, and deployments:

- Vulkan Safety Critical (SC) is working to bring GPU graphics and compute to markets such as automotive, robotics, and avionics that need streamlined system safety certification;
- The Vulkan Working Group is standardizing new 3D rendering techniques such as ray tracing and mesh shaders that will enable new levels of realism and performance;
- Languages and compilers are becoming increasingly important in standards for graphics, inferencing and compute. Khronos will continue to build out the open source ecosystem around SPIR-V, including an increasingly close collaboration with LLVM;
- A related growing trend is the use of Intermediate Representations (IRs), such as LLVM and SPIR-V, to enable users with their language of choice—wherever they need to deploy it. The open source clspv compiler for deploying OpenCL C on Vulkan, and MoltenVK to bring Vulkan apps to Apple platforms are great examples;
- For several Khronos standards, such as OpenCL and OpenVX, the need for deployment flexibility, i.e., the ability to ship market-targeted feature sets while being conformant, is becoming more critical to adoption than new functionality. We will be eagerly seeking user feedback on the mechanics of making that a reality.

Looking further out into 2021–22:

- Machine learning uses and technology will continue to rapidly evolve. Standards organizations will be carefully evaluating when there is enough stability to make more interoperability standards practical and valuable, enabling the industry to move from monolithic, often open source implementations to increasingly cross-platform, cross-vendor ML stacks;
- The technology and constellation of standards to enable ever more accessible HMD-based augmented reality will continue to evolve. Market growth will continue to be in enterprise, whereas the engineering and social barriers to widespread head-worn consumer AR will still not be solved;
- 5G edge servers will begin to provide a significant new path to deployment for on-prem AR, visualization, and compute applications. Standards such as Vulkan and OpenXR should be receptive to user requirements that these new deployment architectures generate.

Neil is Vice President of Developer Ecosystems at Nvidia where he helps enable applications to take advantage of advanced GPU and silicon acceleration. Neil is also the elected President of the Khronos Group, where he initiated the OpenGL ES standard now used by billions worldwide every day, helped catalyze the WebGL project to bring interactive 3D graphics to the Web, fostered the creation of the glTF standard for 3D assets, chairs the OpenCL working group defining the open standard for heterogeneous parallel computation, and helped establish and launch the new-generation Vulkan API. Before Nvidia Neil was at the forefront of the silicon revolution bringing interactive 3D to the PC, and he established the embedded graphics division of 3Dlabs to bring advanced visual processing to a wide range of non-PC platforms..

Nick Divehall, Looking ahead to 2020

X5, 5G, and better content

As we near the end of 2019, it appears the AR/VR industry has stalled while everyone awaits Apple to repeat the original iPhone launch success for AR and spark an eagerly anticipated new era of mass spatial computing. However, there is a key difference that Apple had in its favor with the iPhone that does not apply when it comes to their AR launch… Consumer expectations.

Obviously, there were many factors that made the iPhone launch successful; however, who recalls the moment during the original iPhone launch that had the audience audibly gasp? It was seeing the slick buttery smooth graphics of the iOS UX compared to the utilitarian kludge of everything that had come before Consumers were being shown something beyond how they imagined using a phone could be, and for many of them it was magic.

I believe this bright and sparkly future of AR mass adoption is further away and will be much more technically and commercially challenging than people expect. When it comes to the general consumer's expectations of a spatial UX everyone has their primary experience interacting with the real world as an intuitive reference. They also watch fantastical realistically rendered worlds in movies and they have magical realtime 3D experiences in the games they play. While 3D tech nerds are absorbed watching the progress of each incremental step in a complex combination of AR/VR technologies (rendering, compute, sensor, tracking, optical, AI/ML, speeds, feeds and pixels, etc.), they forget that the general consumer does not care to understand the technical limitations preventing the translation of expectations set by reality and current 3D technology realism and UX, when the virtual world has to intersect with physical reality.

Today Big Tech runs on mining data to monetize interactions-of-value constrained to a 2D screen (Search, Google AdWords, Social Media, Amazon, etc.). The goal for the future of Big Tech will be mining realtime data generating dynamic interactions-of-value as a 3D experience overlaid on reality. A 5th "data" dimension constantly simulating and dynamically generating potential realities customized for every individual to choose from or have AI delegated to generate for them.

Once you begin to fully imagine a "post-screen" tech economy and the infrastructure required to achieve this at scale you begin to realize the enormity of the infrastructure problem to ingest and compute the data for all industries and businesses to generate the magic moment of a "Personalized Reality" tailored for each individual on the fly.

Hiding behind the rather banal banner of "5G" is the associated GPU-based edge network infrastructure. Today's Content Delivery Networks (CDN's) cache the website data of distant servers at the closest point to an internet user, ensuring websites are served up snappy. With the

rollout of 5G, GPUs will be packed everywhere in wireless transmission towers, Wi-Fi routers, on-premise and in the Cloud. Alongside the ultra-fast wireless 5G spectrum, the GPU Edge will dynamically compute AI, Ray Tracing, 3D, Video, Spatial and other processing tasks. Offloading compute at the edge lowers the power requirements for lightweight AR and enables the autonomous industry while greatly reducing latency.

In effect, the 5G era is the inflection point of a new compute platform, internet, and UX paradigm combined. How this might unfold raises many questions and potential implications for not just AR, but the tech industry overall.

Clearly, this will shake up the digital content, CAD, and game engine market and the decades-old codebases on which this industry runs today. It also has the potential to create dramatic tension and disruption in the current Telco, device, cloud and GPU landscape. Apple is weak when it comes to cloud offerings and has a Teleco industry determined not to let Apple undermine them again with an iPhone like AR launch that might interfere with their 5G ambitions. Not to mention the current geopolitics of Huawei and the US–China trade war driving a potential bifurcation of global compute-platforms and the internet.

Have your popcorn ready, this will be fun to watch in 2020!

Nick Divehall is a technology executive with over 20 years of global experience. He has led Academy Award-winning software vendors with his entrepreneurial, sales, and business development acumen holding Global roles based in California and Asia Pacific-wide roles based in Japan and Singapore. He is an entrepreneur who has founded multiple companies and a technology angel investor.

Ted Pollak, 2019 game tech review

Play video games anywhere

2019 in gaming doesn't need a lot of discussing because on most fronts not a lot happened. This was a year of incremental advances. Bigger, better games. Faster CPUs. More features and speed for GPUs. Better HMDs.

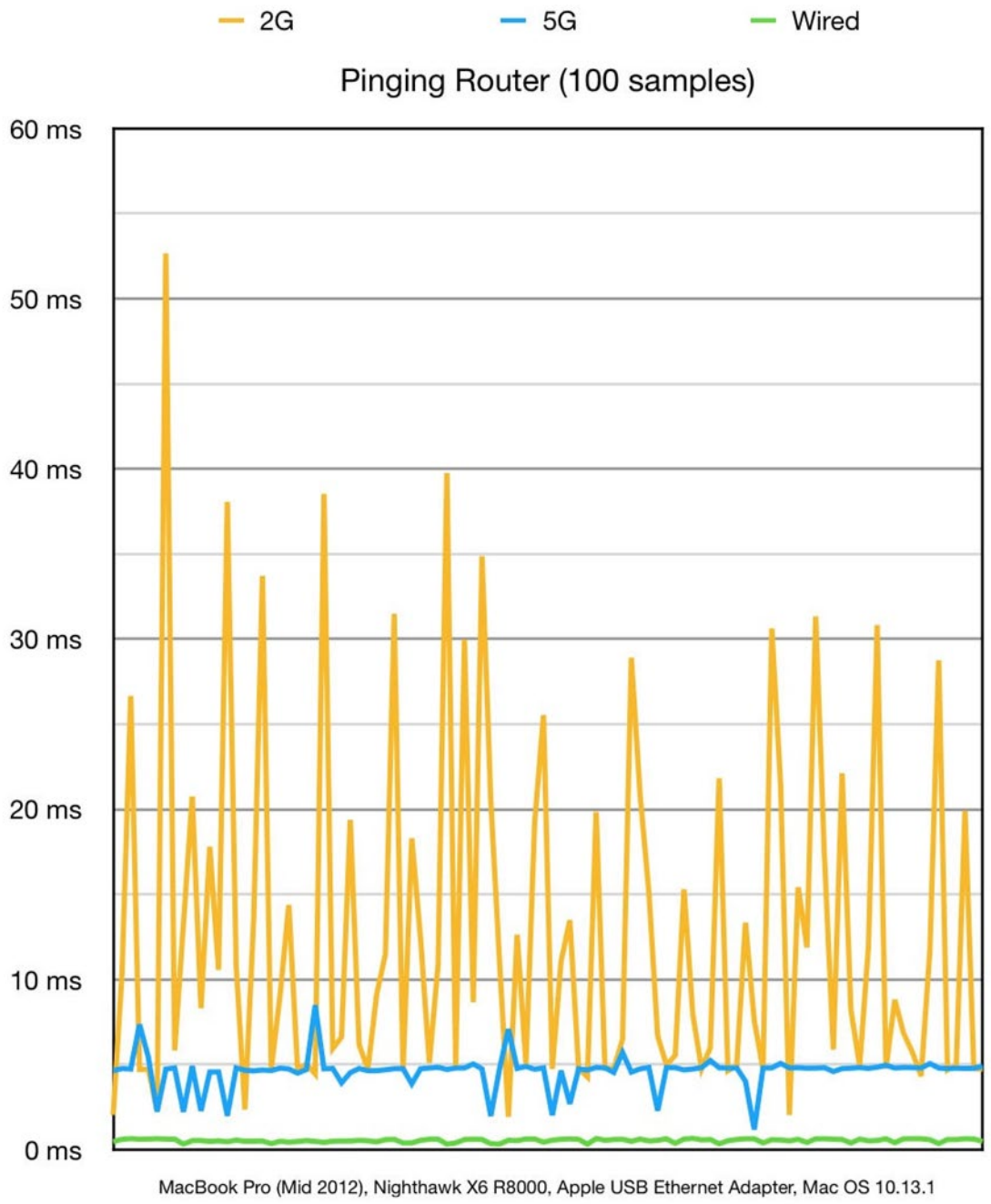
However, there was one thing that was truly revolutionary. The Google Stadia launch. Cloud gaming had been done before. But these efforts have been nowhere near the scale or executed in the advanced way Google is doing it. Will it be a good business? Time will tell. One market research analyst has already stated that Stadia was dead on arrival.

I don't buy that and think it will persist and possibly flourish. One reason being is that it synergizes with other things that Google does. Remote GPU computing has many applications. YouTube is part of the deal. Google can't afford to let Apple, Amazon, or Samsung dominate the TV OS market. Another reason is that Stadia likely is not very expensive for Google and has a low break even per user. They certainly didn't spend a lot on marketing.

There has been nothing in the past ten years that has the potential to change the way people access video games as much as cloud gaming.

So the remainder of this article will be an evaluation of our experience with Stadia. We placed an order for the Premiere Edition bundle which comes with the controller, a Chromecast Ultra, and three months of Stadia Pro. Stadia Pro gives you access to some free games and 4K HDR functionality. It runs $10 a month after the promotion ends. The bundle was around $130. A Chromecast Ultra itself costs about $70 and is an extremely useful portable device for streaming content to large displays, which gives the deal a nice sweetener perhaps comparable to the DVD functionally in Sony PlayStation history.

The initial setup was pretty easy. I placed it upstairs in my loft home/office in the bedroom. There is no Ethernet connection up there and this was purposeful. I wanted to evaluate if the service is viable over 5G Wi-Fi. The answer to that is dependent on many things. Connection latency to Stadia server, distance to router if using Wi-Fi, and the game type. Obviously, one of the most important is the base latency from the servers to the router. Depending on your specific router, 5G wireless introduces about 5 to 10 ms of latency over a wired Ethernet connection. 2G can add up to 60 ms. We found a nice test conducted by Parsec Gaming to illustrate this phenomenon.



Router latency test. (Source: Parsec Gaming)

The first game I tried was *Destiny 2*. This is the most demanding type of game for cloud gaming because it's a multiplayer twitch shooter. My sensitivity to latency, trying not to sound arrogant, is higher than most humans. When I played the shooter circuits in the Quake era, I would consistently rank at or near the top of the leaderboard. I was the master of the railgun; the most difficult weapon because it has no shot spread or splash damage. When you are moving through

low gravity space with six degrees of freedom and aiming at another player also moving through space that way, triangulating and timing a rail gun shot is the ultimate display of precision and twitch reflexes. I must admit, I did feel latency with Stadia in Wi-Fi mode (with the router downstairs) in this game. However, I am pretty sure that shaving about 7 ms off and I would not feel it. I think many people wouldn't feel the latency over Wi-Fi but the lesson here is that hooking the Chromecast Ultra to an Ethernet cable is probably a good idea for twitch shooter fans.

After testing *Destiny 2*, I bought a game that I have actually been wanting to play. *Assassins Creed Odyssey*. Ironically, I had already bought it for PC, but unbelievably even though I downloaded it from Uplay, the developers own platform, there was a fatal mouse glitch they could not solve that prevented me from getting past the main menu. UbiSoft refunded my purchase after considerable tech support.

JPR Game Genre Sample Latency Estimates	
Game Genre	Optimal Maximum Latency
Multiplayer Twitch Shooter	60ms
Single Player Shooter	65ms
Action Adventure Game	70ms
RPG	70ms
RTS	75ms
Casual Games	90ms
Turn Based Games	120ms

This game's genre is known by some as Action Adventure. *Tomb Raider* is another famous title from this genre. And so far it's been almost perfect in performance. No worse than the glitches and crashes I have had on PC or console.

Conclusion: 2019 in video games can be summed up in one word: Stadia.

Ted Pollak has been following the video game industry for over 20 years. The majority of Ted's career has been in the field of investment management where he has experience with companies such as Wells Capital Management, SDR Capital Management, and Hambrecht & Quist. Combining his knowledge of games and finance, he founded and launched the Electronic Entertainment Fund, an investment partnership focused on entertainment technology, multiple financial products including the publicly listed GAMR ETF. Ted is the Senior Gaming Analyst for JPR, where he contributes to TechWatch, writes an industry report, and provides consulting in various areas of entertainment technology.