EIPC SPEeDNEWS

The Weekly On-Line Newsletter from the European Institute of Printed Circuits.
Issue 18 - June 2021

NEWS FROM AUSTRIA

AT&S Supervisory Board approves investment project in Southeast Asia

The Supervisory Board of AT&S AG, one of the leading manufacturers of high-end printed circuit boards and IC substrates, unanimously approved an investment in a new location in Southeast Asia at its meeting today and agreed to the project. This is set to become the largest investment in AT&S's corporate history, as announced in an Ad-Hoc release on June 1, 2021.

An investment of up to EUR 1.7 billion is planned for the project – the construction of a production site for high-end substrates in Southeast Asia – between 2021 and 2026, and a total of 5.000 additional jobs will be created. At the same time, the company headquarters in Leoben-Hinterberg will be expanded, which will thus not only remain the company's hub and pivot, but will also gain additional importance in the area of research and expanded production possibilities.

AT&S grows by double digits in the corona year 2020/21

- **Record revenue of € 1,188.2 million (+18.8%), 23% revenue increase in Q4**
- **Demand for ABF substrates continues unabated**
- **Production start at plant III in Chongqing to be brought forward – ramp-up in the current financial year**
- **EBITDA of € 245.7 million nearly at historic high, EBITDA margin improved from 19.4% to 20.7%**
- **Outlook 2021/22: revenue growth of 13 to 15%, adjusted EBITDA margin in the range from 21 to 23%**

AT&S closed a challenging year – marked by the corona pandemic – with an impressive performance and achieved a double-digit increase in revenue and earnings.

"With this performance, we have once again proven our resilient business model and demonstrated that we continuously develop even in times of uncertainty. We are growing faster than the market while being highly profitable. In the past, we created the basis that

enables us to respond quickly and consistently work on advancing our growth strategy at the same time. We are fully on track to achieve our goals," says CEO Andreas Gerstenmayer.

Consolidated revenue was at a record level of € 1,188.2 million (PY: € 1,000.6 million), up 19% year-on-year. Adjusted for currency effects, consolidated revenue even rose by 22%. The additional capacity from the Chongqing I plant, which serves the growing demand for ABF substrates, made a significant contribution to revenue growth. In the Mobile Devices & Substrates segment, the broader customer and application portfolio for mobile devices and demand for printed circuit boards for modules also had a positive effect. In the AIM segment, revenue in the Medical segment was at the prior-year level while revenue in the Industrial segment increased slightly. After a weak first half of the financial year, the Automotive segment recorded revenue in the second half at the level of the previous year.

EBITDA amounted to € 245.7 million (PY: € 194.5 million) and nearly matched the historic high of the financial year 2018/19. The earnings improvement is predominantly attributable to the higher consolidated revenue. Currency effects, in particular due to the weaker US dollar, had a negative impact on the revenue and earnings development. The **EBITDA margin** amounted to 20.7%, thus exceeding the prior-year level of 19.4%. EBIT improved from € 47.4 million to € 79.8 million. The EBIT margin was at 6.7% (previous year: 4.7%).

Finance cost – net changed from € -8.7 million to € -20.1 million primarily due to currency effects. Net profit for the year rose from € 19.8 million in the previous year to € 47.4 million as a result of the significant increase in the operating result.

The financial position at year-end is characterised by the increase in non-current assets. Total assets rose by 28.9% year-on-year to € 2,390.0 million as a result of additions to assets and technology upgrades.

Equity increased by 5.5% year-on-year and amounted to € 802.0 million, primarily due to the increase in net profit for the year. The equity ratio declined from 41.0% in the previous year to 33.6% in the reporting year and fell short of the medium-term target of 40.0%. This is attributable in particular to the increase in total assets as a result of investments and securing the financing of the future investment programme.

Cash and cash equivalents rose to € 552.9 million (PY: € 418.0 million). In addition, AT&S has financial assets of € 39.7 million and unused credit lines of € 418.6 million to ensure financing of the future investment programme and short-term repayments.

"AT&S is economically stable and has a solid balance sheet structure, which was further strengthened by capital measures in the past year. To secure financing of the upcoming investments and ongoing business activities, we will continue to optimise and expand our capital structure," says CFO Simone Faath.

FINANCIALS Acc. to IFRS; (in EUR million)	FY 2019/20 01.04.2019- 31.03.2020	FY 2020/21 01.04.2020- 31.03.2021	Change
Group			
Revenue	1,000.6	1,188.2	18.8%
EBITDA	194.5	245.7	26.3%
EBITDA margin (in %)	19.4	20.7	-
EBIT	47.4	79.8	68.3%
EBIT margin (in %)	4.7	6.7	-
Profit/loss for the period	19.8*	47.4	>100%
Cash flow from operating activities	185.1	184.7	(0.3%)
Net CAPEX	218.5	435.8	99.4%
Equity Ratio (in %)	41.0	33.6	-
Net debt	246.7	508.5	>100%
Earnings per share	0.30	1.01	>100%
* Adjustment hedge accounting previous year			

Showing 1 to 12 of 12 entries

Outlook 2021/22
The global trend towards a digital society will continue to progress in the financial year 2021/22. The use of ever smarter devices, i.e. devices equipped with intelligence, and increasing interconnection are generating exponential data volume growth. With its solutions and services, AT&S is excellently positioned in all market segments affected by this development. AT&S will exploit the business opportunities arising from this development in order to grow profitably and faster than the market in the future. To enhance our performance, we consistently invest large sums in technology and capacity expansion. Our long-term corporate goals reflect our clear growth ambitions in profitable market segments and applications.

The positive outlook of the electronics industry is currently dampened by a shortage of semiconductors. The expectations for AT&S's segments are currently as follows: the persisting strong demand for IC substrates continues to offer significant growth opportunities in the medium term. The 5G mobile communication standard will continue to drive growth in the area of Mobile Devices. An upturn is expected in the Automotive segment despite the semiconductor shortage. Driven by a boom in industrial robots and the roll-out of the 5G infrastructure, the Industrial segment will continue to see a positive development in the coming year. AT&S expects a positive development in the Medical segment for the current financial year.

Operationally, AT&S will concentrate on the start-up of the new production capacities at plant III in Chongqing, carry out technology upgrades at other locations and continue to drive its business performance.

Investments

"The market for communication infrastructure, which is responsible for data transmission, is booming and so is demand for processing capacity. Digitisation in all areas of life will continue to develop dynamically. Therefore, we are investing in additional capacity and are significantly expanding our market position of ABF substrates," says Andreas Gerstenmayer.

Up to € 100 million is budgeted for basic investments (maintenance and technology upgrades) depending on market development. As part of the strategic projects, the management is planning investments totalling up to € 450 million for the financial year 2021/22 depending on the progress of projects, plus another € 80 million due to period shifts between the financial years.

Guidance for the financial year 2021/22

Against the background of the expectations for global economic growth, of the available capacities and the markets relevant to AT&S as described above, the company expects revenue growth of 13 to 15% in the financial year 2021/22, assuming a euro/US dollar exchange rate of 1.18. Taking into account special effects amounting to approximately € 40 million from the start-up of new production capacities in Chongqing, the adjusted EBITDA margin is expected to range between 21 and 23%.

NEWS FROM FINLAND

Aspocomp has signed two significant project agreements with a customer in the automotive segment

Aspocomp Group Plc has signed two significant project agreements for supplying printed circuit boards (PCBs) to a customer in the automotive industry.

The combined value of these multi-year agreements, if realized, will be over EUR 30 million over the lifetime of the projects. The volume deliveries are planned for 2022 – 2030. These agreements have no effect on Aspocomp's net sales and operating result for 2021.

The Electronic Control Unit PCBs (ECU-PCB) are used in Automated Manual Transmission solutions (AMT). By using this system, the benefits of automatic transmission can be achieved while keeping the advantages of manual transmission such as energy efficiency and driveability.

Aspocomp has extensive experience in advanced and safety-related automotive PCBs. The long-standing customer relationship with the automotive segment OEM and these agreements are a good complement to Aspocomp's typical portfolio of QTA prototyping PCB supply.

NEWS FROM ITALY

Seica SpA launches the LED Sensor Option for the Pilot Line

Following the boost to energy saving and today's improved design technology, the LED type components really replaced almost any other light source.

LED modules can be found in any market sector, starting from Automotive, bringing production levels of this type of boards to unconceivable amounts.

Need for accurate Testing
Typically we talk about simple boards from a circuitry point of view, but requiring an accurate testing. Approximations and compromises can be made, however, the only way to ensure the quality of the product is the functional testing, along with the characterization of each LED through dedicated sensors. For productions of consistent codes, assembled in large volumes, it is possible to implement dedicated but definitely expensive test fixtures. In all the other instances, the flying probe platform comes in, providing to date a test speed which meets the pace of the production output.

Can be equipped with the "Led Sensor" option.

This is a FEASA sensor which can be installed on one or more heads, and can test the featuring settings of a Led: colour, intensity and saturation. FEASA is a renowned manufacturer of sensors which are globally acknowledged as the standard for Led characterization.

IMPLEMENTATION Features

- Need to test **Led board panels up to 1500 mm length**

- The system can be managed both in-line or as a stand-alone test station.

- A flying prober with '**LED SENSOR**' option can be perfectly integrated into a high-volume automatic production line.

- Configuration with 4 electrical probes and two FEASA sensors

- SPLIT TEST available for boards exceeding 600 mm length.

- External automatic conveyors to support the **D.U.T.** (both incoming and outgoing)

- Timely verification of positioning, colour, saturation and intensity parameters for each Led

- Power pads required on the whole board

- Power supplied via flying probes

BENEFITS:

- Effective testing of the board and characterization of the main components

- Possibility of a stable and reliable inspection downstream of the production

- Fast and reliable programming, possibility of ICT test on the circuitry

- The SPLIT TEST function allows to test the panel by steps, having it conveyed consistently with the test execution

- Streamlined handling of relevant size panels

- Improved quality of the finished product

- Consistent quality control of the incoming components

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NEWS FROM PRODUCTRONICA

MESSE MÜNCHEN WELCOMES A POSITIVE SIGNAL FOR OPENINGS IN FALL—"VCR" CONCEPT IN USE AS OF PILOT TRADE FAIR IN JULY 2021

Trade fairs and events will once again be possible in the Bavaria no later than September 1, 2021. The Bavarian State Government gave this positive signal in their cabinet meeting on May 18, 2021. The main requirement for the resumption of trade fairs will be the continued positive development of COVID-19 infection rates. With this, the way is also clear politically for upcoming in-person events such as IAA MOBILITY and EXPO REAL. For test purposes the TrendSet symposium will take place as a pilot project on the Munich trade fair grounds from July 10 to 12. An elaborate infection-prevention and hygiene concept will be tested as part of the fair.

Klaus Dittrich, Chairman and CEO of Messe München, was relieved at this positive signal from the state chancellery: "This decision now gives us and our customers the necessary planning security for the upcoming fall events. With our safety and hygiene concept, we are already ideally prepared for trade fairs such as IAA MOBILITY, OutDoor by ISPO, EXPO REAL and productronica. We are also very encouraged by the lifting of travel restrictions and the rising rate of immunizations. The decision is also an important signal for the business community in the region. The trade-fair industry is one of the leading economic engines of Munich and Upper Bavaria."

PILOT PROJECT TRENDSET IN JULY

The State Government is currently working on a framework for hygiene and safety provisions for trade fairs and events in Bavaria. This is to be tested at a pilot project in July. The state chancellery has chosen TrendSet in Munich for this purpose. The symposium for interior and lifestyle will take place from July 10 to 12 at the grounds of Messe München and had already successfully completed an event within the framework of the prescribed safety measures in fall 2020.

SAFETY AND HYGIENE CONCEPT OF MESSE MÜNCHEN

In recent months, the safety and hygiene concept implemented at that time has been adapted and expanded by Messe München in accordance with current developments.

Among other things, the concept comprises specifications and regulations with regard to the social distancing of the participants, the ventilation of the exhibition halls, the wearing of FFP2 masks, as well as hygiene provisions on site and the traceability of all participants.

As soon as the latest framework for hygiene and safety provisions at trade fairs and events from the Bavarian State Government is available, Messe München will make further adjustments.

The "VCR" concept is to take on a decisive role in this context. This stipulates that, in order to be admitted, all participants at the pilot project and all upcoming events must meet the following criteria: vaccinated, checked or recovered. For this purpose, in addition to decentralized tests, Messe München is planning its own test capacities in order to ensure the health and safety of all participants.

EDITOR'S NOTE

If one goes to the Productronica website there is a note which reads as follows:-

2021 productronica
Cancelled
Location: MESSE MÜNCHEN GMBH, Internationales Congress Center München

However, a telephone call to their Press Office revealed that Productronica
WILL BE HELD ON 16th – 19th November 2021

SURFACE MOUNT INDUSTRY NEWS

Webinar: High Thermal Demand Applications
Ask the Experts During This Special Presentation

Join us to learn more about how the consumer and electronics industries are meeting the challenges of high thermal demand applications. This is a great opportunity to be part of the discussion focused on how to meet challenges in soldering highly metalized components and PCBs from top industry experts:

Tim O'Neill
The Director of Product Management for AIM Solder, Mr. O'Neill has 25 years of industry experience is a Certified IPC Specialist.

Carlos Salinas
The Production Manager of Revco Products, Inc., Mr. Salinas is well versed in process development and implementation, SMT & THT lines, soldering, x-ray inspection, and conformal coating.

Ed Zamborsky

As a technology adviser for METCAL™ product development, Ed has authored articles and presented papers on topics such as Low Volume SMT Assembly, Solder Fume Extraction, Lead Free Hand Soldering, Lead Free Visual Inspection and Lead Free Array Rework.

Chrys Shea

Moderating the discussion will be Chrys Shea, President of Shea Engineering Services. Chrys is an SMTA "Member of Technical Distinction" and three-time SMTAI "Best of Conference" award winner for her research on solder paste printing.

Registration is now open – don't miss it.

Date: Monday, June 14
Time: 9 AM Pacific

Register Now

Download Metcal's New Inductive Soldering for High Thermal Demand Applications Whitepaper to Learn:

- Soldering Challenges of Highly Metalized Components and PCBs

- Difficult to Solder Components

- Compensation Methods and Potential Risks

- Industry Standards for Soldering

- Inductive vs. Resistive Soldering

- Benefits of Inductive Soldering

DOWNLOAD WHITEPAPER

Visit Metcal Website and Solutions pages to learn more about the GT Series adjustable temperature soldering with inductive heating.

ELECTRONIC INDUSTRY NEWS

Location, Location, Location

By Rebecca Day

Location, location, location. That's a buzzword in the techsphere these days with Apple launching its Bluetooth trackers in April and Tile due to join the Amazon Sidewalk network mid-June. Thanks to these tiny adhesive-backed trackers, we can keep track of items we don't want to lose. Who knew we misplaced so many things?

The object I'm most concerned about losing is my phone, but you need the phone to locate the AirTag via the Find My app, so if I lose my phone, it can't find itself if I leave it at a store.

But that didn't stop me from getting a couple. I'm a sucker for an Apple product that sells for fewer than three figures, even if I don't know what I'll do with it. The $29 investment in the tracker left room in the budget for accessorizing, too. I got a sharp-looking brown leather housing to fit over the tiny tag that's the size of a couple stacked quarters, and I stuck it on a key ring. And because I could get two tags and the handsome leather case for under $100, I did.

Keys are one of the suggested use cases for the AirTag that Apple offers up, in case you can't decide where to plant one. The other things Apple thinks you'll lose include handbags and headphones, backpacks, jackets, luggage, wallets and umbrellas. I like my bumbershoot, but I wouldn't spend $29 to track a $16 item. Where would you put one on an umbrella, anyway?

You can give your precious object a custom name, which will pop up on your phone when you go into the Find My app. Cute little icons for things like keys and cars show up in Maps, which gives you directions to the item if you need them. That could come in handy for the

collar of a St. Bernard who likes to explore the neighbourhood, but Apple says tags aren't meant to find Fido. That hasn't stopped a pack of dog collar companies from selling them on Amazon.

I'm guessing Apple doesn't want responsibility for Fido, who might wander beyond the Find My range, and the owner would then only see the last known location of the pup rather than the true location.

AirTags locate nearby lost items using Precision Finding, enabled by the U1 chip in the iPhone 11 and 12 that uses ultrawideband for location down to the foot when the devices are in Bluetooth range of each other.

Apple says Precision Finding "fuses input from the camera, ARKit, accelerometer, and gyroscope, and then will guide them to AirTag using a combination of sound, haptics, and visual feedback." It was fun when the tactile pulses in my phone sped up as I got warmer to my keys in the other room, which the app told me were 13 feet away. That was as the crow flies in my apartment; they were more like 20 feet away since I can't walk through walls.

If you're beyond Precision Finding range, the crowd sourced find my network takes over. "Millions" of Bluetooth-enabled Apple devices "detect missing devices or items nearby, and report their approximate location back to the owner," Apple says. The company promises the entire process is "end-to-end encrypted and anonymous, so no one else, not even Apple or the third-party manufacturer, can view a device's location or information."

Even Good Samaritan Android users can play lost and found via the NFC chip in their phones. They place their phone near an AirTag, and once scanned, an alert pops up directing them to a link if the tag has been logged as lost. They get instructions on how to contact the tag's owner and return the item to them. That sounds like a lot of work, but random acts of kindness do happen.

The other item I wanted to monitor, our car, wasn't on the list of Apple's suggested items to track. Maybe Apple figures most people's cars live in their garages and are pretty easy to find, though enough trips up and down the rows of a Target parking lot after forgetting where you parked would be a valid reason to have a tracker in it.

I live in New York City and have to move the car a couple of times a week for alternate-side-of-the-street parking. And a couple of times a month I forget where the car is parked. It's embarrassing to walk up and down the streets of Greenwich Village hunting for a car, so the tracker can lead me back to the spot of the last parallel parking challenge before I have to do it all over again.

Of course, I didn't need to pay $29 for a tracking disk to show me the car on an app: I already had that capability in Maps, which drops a parked car pin when I leave the vehicle. Still, I discreetly placed an AirTag in the car anyway as a low-cost Lo-Jack alternative. Apple doesn't encourage that, either, but I figure it can't hurt. If my tracker hasn't communicated with my phone in three days, it will start to beep, so I can see why it's not the best stolen car

tracker, but as someone on an Apple discussion board said, "you still have time to find your car before it tells the thief he's being stalked by a foreign AirTag."

Speaking of stalking, Apple took into account nefarious uses of the tiny devices and gives them the power to "discourage unwanted tracking." If someone tries to plant an AirTag on me to find out where I live, my iPhone will suss out the alien Bluetooth signal and alert me that an unknown AirTag is there.

Reedit is full of questions about AirTags, like what if you're at work and run to Starbucks for coffee but leave your keys on your desk? Do your co-workers' iPhones start beeping because an unknown AirTag is nearby? There's little incentive to steal an AirTag since one device can't be paired with more than one phone, but that brought questions about family sharing. What happens if your wife takes your luggage on a trip, and there's an AirTag attached to your iPhone ID?

Other points of confusion: how AirTags affect a phone's battery life and whether phones that don't have the latest iOS update can get AirTag alerts. What happens if someone attaches an AirTag to another person's Android phone? Will they get stalking alerts like an iPhone does?

A lot goes on in the AirTag world that we don't actually see. There's no display on the device itself and you can't power it on or off. Apple says battery life is over a year, but already some users are complaining they've had to replace theirs. Me? I'm still trying to find a really good use case for one. If it could only find the car and park it, too.

Rebecca Day

Rebecca Day is Senior Editor

Researchers demonstrate a quantum advantage

By University of Arizona

University of Arizona researchers demonstrate a quantum advantage. Credit: University of Arizona

Quantum computing and quantum sensing have the potential to be vastly more powerful than their classical counterparts. Not only could a fully realized quantum computer take just seconds to solve equations that would take a classical computer thousands of years, but it could have incalculable impacts on areas ranging from biomedical imaging to autonomous driving.

However, the technology isn't quite there yet.

In fact, despite widespread theories about the far-reaching impact of quantum technologies, very few researchers have been able to demonstrate, using the technology available now, that quantum methods have an advantage over their classical counterparts.

In a paper published on June 1 in the journal *Physical Review X*, University of Arizona researchers experimentally show that quantum has an advantage over classical computing systems.

"Demonstrating a quantum advantage is a long-sought-after goal in the community, and very few experiments have been able to show it," said paper co-author Zheshen
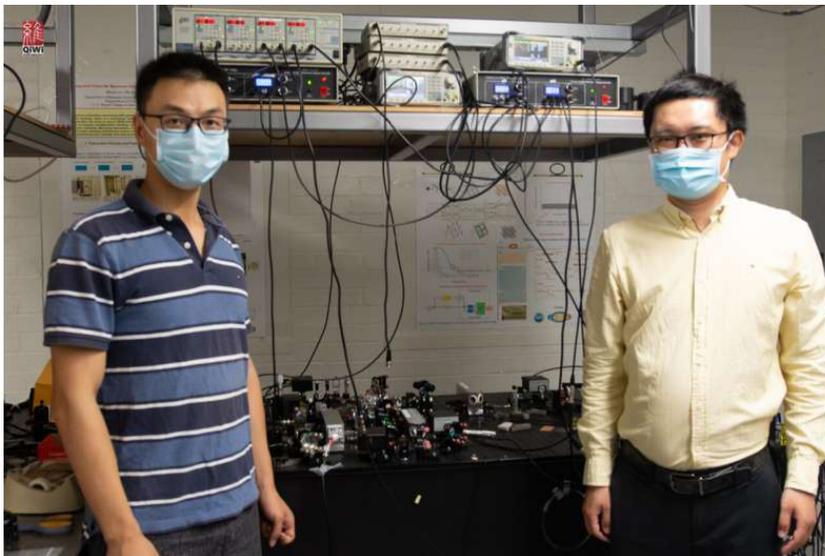
Zhang, assistant professor of materials science and engineering, principal investigator of the UArizona Quantum Information and Materials Group and one of the paper's authors. "We are seeking to demonstrate how we can leverage the quantum technology that already exists to benefit real-world applications."

How (and When) Quantum Works

Quantum computing and other quantum processes rely on tiny, powerful units of information called qubits. The classical computers we use today work with units of information called bits, which exist as either 0s or 1s, but qubits are capable of existing in both states at the same time. This duality makes them both powerful and fragile. The delicate qubits are prone to collapse without warning, making a process called error correction—which addresses such problems as they happen—very important.

The quantum field is now in an era that John Preskill, a renowned physicist from the California Institute of Technology, termed "noisy intermediate scale quantum," or NISQ. In the NISQ era, quantum computers can perform tasks that only require about 50 to a few hundred qubits, though with a significant amount of noise, or interference. Any more than that and the noisiness overpowers the usefulness, causing everything to collapse. It is widely believed that 10,000 to several million qubits would be needed to carry out practically useful quantum applications.

Imagine inventing a system that guarantees every meal you cook will turn out perfectly, and then giving that system to a group of children who don't have the right ingredients. It will be great in a few years, once the kids become adults and can buy what they need. But until then, the usefulness of the system is limited. Similarly, until researchers advance the field of error correction, which can reduce noise levels, quantum computations are limited to a small scale.

Quntao Zhuang (left), PI of the Quantum Information Theory Group, and Zheshen Zhang, PI of the Quantum Information and Materials Group, are both assistant professors in the College of Engineering. Credit: University of Arizona

Entanglement Advantages

The experiment described in the paper used a mix of both classical and quantum techniques. Specifically, it used three sensors to classify the average amplitude and angle of radio frequency signals.

The sensors were equipped with another quantum resource called entanglement, which allows them to share information with one another and provides two major benefits: First, it improves the sensitivity of the sensors and reduces errors. Second, because they are entangled, the sensors evaluate global properties rather than gathering data about specific parts of a system. This is useful for applications that only need a binary answer; for example, in medical imaging, researchers don't need to know about every single cell in a tissue sample that isn't cancerous—just whether there's one cell that is cancerous. The same concept applies to detecting hazardous chemicals in drinking water.

The experiment demonstrated that equipping the sensors with quantum entanglement gave them an advantage over classical sensors, reducing the likelihood of errors by a small but critical margin.

"This idea of using entanglement to improve sensors is not limited to a specific type of sensor, so it could be used for a range of different applications, as long as you have the equipment to entangle the sensors," said study co-author Quntao Zhuang, assistant professor of electrical and computer engineering and principal investigator of the Quantum Information Theory Group"In theory, you could consider applications like lidar (Light Detection and Ranging) for self-driving cars, for example."

Zhuang and Zhang developed the theory behind the experiment and described it in a 2019 Physical Review X paper. They co-authored the new paper with lead author Yi Xia, a doctoral student in the James C. Wyant College of Optical Sciences, and Wei Li, a postdoctoral researcher in materials science and engineering.

Qubit Classifiers

There are existing applications that use a mix of quantum and classical processing in the NISQ era, but they rely on pre-existing classical datasets that must be converted and classified in the quantum realm. Imagine taking a series of photos of cats and dogs, then uploading the photos into a system that uses quantum methods to label the photos as either "cat" or "dog."

The team is tackling the labelling process from a different angle, by using quantum sensors to gather their own data in the first place. It's more like using a specialized quantum camera that labels the photos as either "dog" or "cat" as the photos are taken.

"A lot of algorithms consider data stored on a computer disk, and then convert that into a quantum system, which takes time and effort," Zhuang said. "Our system works on a different problem by evaluating physical processes that are happening in real time."

The team is excited for future applications of their work at the intersection of quantum sensing and quantum computing. They even envision one day integrating their entire experimental setup onto a chip that could be dipped into a biomaterial or water sample to identify disease or harmful chemicals.

"We think it's a new paradigm for both quantum computing, quantum machine learning and quantum sensors, because it really creates a bridge to interconnect all these different domains," Zhang said.

Artificial intelligence won't be very smart if computers don't grasp cause and effect. That's something even humans have trouble with.

In less than a decade, computers have become extremely good at diagnosing diseases, translating languages, and transcribing speech. They can outplay humans at complicated strategy games, create photorealistic images, and suggest useful replies to your emails.

Yet despite these impressive achievements, artificial intelligence has glaring weaknesses.

Machine-learning systems can be duped or confounded by situations they haven't seen before. A self-driving car gets flummoxed by a scenario that a human driver could handle easily. An AI system laboriously trained to carry out one task (identifying cats, say) has to be taught all over again to do something else (identifying dogs). In the process, it's liable to lose some of the expertise it had in the original task. Computer scientists call this problem "catastrophic forgetting."

These shortcomings have something in common: they exist because AI systems don't understand causation. They see that some events are associated with other events, but they don't ascertain which things directly make other things happen. It's as if you knew that the presence of clouds made rain likelier, but you didn't know clouds caused rain.

Elias Bareinboim: AI systems are clueless when it comes to causation.

Understanding cause and effect is a big aspect of what we call common sense, and it's an area in which AI systems today "are clueless," says Elias Bareinboim. He should know: as the director of the new Causal Artificial Intelligence Lab at Columbia University, he's at the forefront of efforts to fix this problem.

His idea is to infuse artificial-intelligence research with insights from the relatively new science of causality, a field shaped to a huge extent by Judea Pearl, a Turing Award–winning scholar who considers Bareinboim his protégé.

As Bareinboim and Pearl describe it, AI's ability to spot correlations—e.g., that clouds make rain more likely—is merely the simplest level of causal reasoning. It's good enough to have driven the boom in the AI technique known as deep learning over the past decade. Given a great deal of data about familiar situations, this method can lead to very good predictions. A computer can calculate the probability that a patient with certain symptoms has a certain disease, because it has learned just how often thousands or even millions of other people with the same symptoms had that disease.

But there's a growing consensus that progress in AI will stall if computers don't get better at wrestling with causation. If machines could grasp that certain things lead to other things, they wouldn't have to learn everything anew all the time—they could take what they had learned in one domain and apply it to another. And if machines could use common sense we'd be able to put more trust in them to take actions on their own, knowing that they aren't likely to make dumb errors.

Today's AI has only a limited ability to infer what will result from a given action. In reinforcement learning, a technique that has allowed machines to master games like chess and Go, a system uses extensive trial and error to discern which moves will essentially cause them to win. But this approach doesn't work in messier settings in the real world. It doesn't even leave a machine with a general understanding of how it might play other games.

An even higher level of causal thinking would be the ability to reason about why things happened and ask "what if" questions. A patient dies while in a clinical trial; was it the fault of the experimental medicine or something else? School test scores are falling; what policy changes would most improve them? This kind of reasoning is far beyond the current capability of artificial intelligence.

Performing miracles

The dream of endowing computers with causal reasoning drew Bareinboim from Brazil to the United States in 2008, after he completed a master's in computer science at the Federal University of Rio de Janeiro. He jumped at an opportunity to study under Judea Pearl, a computer scientist and statistician at UCLA. Pearl, 83, is a giant—*the* giant—of causal inference, and his career helps illustrate why it's hard to create AI that understands causality.

Even well-trained scientists are apt to misinterpret correlations as signs of causation—or to err in the opposite direction, hesitating to call out causation even when it's justified. In the 1950s, for example, a few prominent statisticians muddied the waters around whether tobacco caused cancer. They argued that without an experiment randomly assigning people to be smokers or non-smokers, no one could rule out the possibility that some unknown— stress, perhaps, or some gene—caused people both to smoke and to get lung cancer.

Eventually, the fact that smoking causes cancer was definitively established, but it needn't have taken so long. Since then, Pearl and other statisticians have devised a mathematical approach to identifying what facts would be required to support a causal claim. Pearl's method shows that, given the prevalence of smoking and lung cancer, an independent factor causing both would be extremely unlikely.

Conversely, Pearl's formulas also help identify when correlations can't be used to determine causation. Bernhard Schölkopf, who researches causal AI techniques as a director at Germany's Max Planck Institute for Intelligent Systems, points out that you can predict a country's birth rate if you know its population of storks. That isn't because storks deliver babies or because babies attract storks, but probably because economic development leads to more babies and more storks. Pearl has helped give statisticians and computer scientists' ways of attacking such problems, Schölkopf says.

Judea Pearl: His theory of causal reasoning has transformed science.

Pearl's work has also led to the development of causal Bayesian networks—software that sifts through large amounts of data to detect which variables appear to have the most influence on other variables. For example, GNS Healthcare, a company in Cambridge, Massachusetts, uses these techniques to advise researchers about experiments that look promising.

In one project, GNS worked with researchers who study multiple myeloma, a kind of blood cancer. The researchers wanted to know why some patients with the disease live longer than others after getting stem-cell transplants, a common form of treatment. The software churned through data with 30,000 variables and pointed to a few that seemed especially likely to be causal. Biostatisticians and experts in the disease zeroed in on one in particular: the level of a certain protein in patients' bodies. Researchers could then run a targeted clinical trial to see whether patients with the protein did indeed benefit more from the treatment. "It's way faster than poking here and there in the lab," says GNS cofounder Iya Khalil.

Nonetheless, the improvements that Pearl and other scholars have achieved in causal theory haven't yet made many inroads in deep learning, which identifies correlations without too much worry about causation. Bareinboim is working to take the next step: making computers more useful tools for human causal explorations.

Pearl says AI can't be truly intelligent until it has a rich understanding of cause and effect, which would enable the introspection that is at the core of cognition.

One of his systems, which is still in beta, can help scientists determine whether they have sufficient data to answer a causal question. Richard McElreath, an anthropologist at the Max Planck Institute for Evolutionary Anthropology, is using the software to guide research into why humans go through menopause (we are the only apes that do).

The hypothesis is that the decline of fertility in older women benefited early human societies because women who put more effort into caring for grandchildren ultimately had more descendants. But what evidence might exist today to support the claim that children do better with grandparents around? Anthropologists can't just compare the educational or medical outcomes of children who have lived with grandparents and those who haven't. There are what statisticians call confounding factors: grandmothers might be likelier to live with grandchildren who need the most help. Bareinboim's software can help McElreath discern which studies about kids who grew up with their grandparents are least riddled with confounding factors and could be valuable in answering his causal query. "It's a huge step forward," McElreath says.

The last mile

Bareinboim talks fast and often gestures with two hands in the air, as if he's trying to balance two sides of a mental equation. It was halfway through the semester when I visited him at Columbia in October, but it seemed as if he had barely moved into his office—hardly anything on the walls, no books on the shelves, only a sleek Mac computer and a whiteboard so dense with equations and diagrams that it looked like a detail from a cartoon about a mad professor.

He shrugged off the provisional state of the room, saying he had been very busy giving talks about both sides of the causal revolution. Bareinboim believes work like his offers the opportunity not just to incorporate causal thinking into machines, but also to improve it in humans.

Getting people to think more carefully about causation isn't necessarily much easier than teaching it to machines, he says. Researchers in a wide range of disciplines, from molecular biology to public policy, are sometimes content to unearth correlations that are not actually rooted in causal relationships. For instance, some studies suggest drinking alcohol will kill you early, while others indicate that moderate consumption is fine and even beneficial and still other research has found that heavy drinkers outlive non-drinkers. This phenomenon, known as the "reproducibility crisis," crops up not only in medicine and nutrition but also in psychology and economics. "You can see the fragility of all these inferences," says Bareinboim. "We're flipping results every couple of years."

He argues that anyone asking "what if"—medical researchers setting up clinical trials, social scientists developing pilot programs, even web publishers preparing A/B tests—should start not merely by gathering data but by using Pearl's causal logic and software like Bareinboim's to determine whether the available data could possibly answer a causal hypothesis. Eventually, he envisions this leading to "automated scientist" software: a human could dream up a causal question to go after, and the software would combine causal inference theory with machine-learning techniques to rule out experiments that wouldn't answer the question. That might save scientists from a huge number of costly dead ends.

Bareinboim described this vision while we were sitting in the lobby of MIT's Sloan School of Management, after a talk he gave last fall. "We have a building here at MIT with, I don't know, 200 people," he said. How do those social scientists or any scientists anywhere, decide which experiments to pursue and which data points to gather? By following their intuition: "They are trying to see where things will lead, based on their current understanding."

That's an inherently limited approach, he said, because human scientists designing an experiment can consider only a handful of variables in their minds at once. A computer, on the other hand, can see the interplay of hundreds or thousands of variables. Encoded with "the basic principles" of Pearl's causal calculus and able to calculate what might happen with new sets of variables, an automated scientist could suggest exactly which experiments the human researchers should spend their time on. Maybe some public policy that has been shown to work only in Texas could be made to work in California if a few causally relevant factors were better appreciated. Scientists would no longer be "doing experiments in the darkness," Bareinboim said.

He also doesn't think it's that far off: "This is the last mile before the victory."

What if?

Finishing that mile will probably require techniques that are just beginning to be developed. For example, Yoshua Bengio, a computer scientist at the University of Montreal who shared the 2018 Turing Award for his work on deep learning, is trying to get neural networks—the software at the heart of deep learning—to do "meta-learning" and notice the causes of things.

As things stand now, if you wanted a neural network to detect when people are dancing, you'd show it many, many images of dancers. If you wanted it to identify when people are running, you'd show it many, many images of runners. The system would learn to distinguish runners from dancers by identifying features that tend to be different in the images, such as the positions of a person's hands and arms. But Bengio points out that fundamental knowledge about the world can be gleaned by analyzing the things that are similar or "invariant" across data sets. Maybe a neural network could learn that movements of the legs physically cause both running and dancing. Maybe after seeing these examples and many others that show people only a few feet off the ground, a machine would eventually understand something about gravity and how it limits human movement. Over time, with enough meta-learning about variables that are consistent across data sets, a computer could gain causal knowledge that would be reusable in many domains.

For his part, Pearl says AI can't be truly intelligent until it has a rich understanding of cause and effect. Although causal reasoning wouldn't be sufficient for an artificial general intelligence, it's necessary, he says, because it would enable the introspection that is at the core of cognition. "What if" questions "are the building blocks of science, of moral attitudes, of free will, of consciousness," Pearl told me.

You can't draw Pearl into predicting how long it will take for computers to get powerful causal reasoning abilities. "I am not a futurist," he says. But in any case, he thinks the first move should be to develop machine-learning tools that combine data with available scientific knowledge: "We have a lot of knowledge that resides in the human skull which is not utilized."

Brian Bergstein, a former editor at MIT Technology Review, is deputy opinion editor at the Boston Globe.

Counting the human cost of affordable electronics

Twelve-hour shifts, compulsory overtime and one day off a month are among the practices employed at some China-based factories of Taiwan's tech giants

- By Steven Crook / Contributing reporter
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Few companies have had their names dragged through the mud so comprehensively as Foxconn Technology Group (富士康科技集團), a conglomerate known as Hon Hai Precision Industry Co (鴻海精密) in Taiwan, which operates vast factories in China and other countries.

The first time many people outside of Taiwan heard of Foxconn — the world's largest manufacturer of consumer electronics — was in 2010, when a string of employee suicides attracted global interest.

The company's notoriety grew when it emerged that its response to the deaths included installing nets around staff dormitories to catch suicidal workers. The reports also created a public-relations disaster for Foxconn's best known client, Apple.

Labor groups protest outside a shareholders' meeting held by Foxconn, known in Taiwan as Hon Hai Precision Industry Co, calling the company's factories in China sweatshops.

Photo: Wang Min-wei, Taipei Times

Foreign media eventually shifted their attention elsewhere, but labour activists have been determined to keep up the pressure.

One of Foxconn's most high-profile critics is Jenny Chan, an assistant professor of sociology at Hong Kong Polytechnic University and an advisor to Electronics Watch (EW), an independent monitoring organization that brings together public-sector buyers and civil society groups to achieve greater sustainability in the electronics industry.

"How can we protect workers from being squeezed and forced to accept poverty wages, when manufacturers are trying to cut costs and stay flexible in the supply chain?" asks Chan, co-author of Dying for an iPhone: Apple, Foxconn and the Lives of China's Workers.

Students and Scholars against Corporate Misbehavior protests outside an Apple store in Hong Kong in 2017.

Photo courtesy of Students and Scholars against Corporate Misbehaviour

Neither Foxconn nor Apple responded when asked if they wished to comment on the issues Chan raises.

PRESSURED WORKERS

According to Chan, there are a number of reasons why Foxconn's managers put so much pressure on their workers. The conglomerate sees labour discipline as essential if it's to win high value-added orders, she says.

Members of the Hong Kong-based group Students and Scholars against Corporate Misbehavior protest in Hong Kong in 2010.

Photo courtesy of Students and Scholars against Corporate Misbehaviour

Like many companies, Apple operates on a "just in time" basis to minimize inventory carrying costs, so its suppliers must be able to ramp up output ahead of product launches and peak sales periods. Compulsory overtime is frequent, and workers are sometimes denied leave, Chan says.

Until 2010, Foxconn was the exclusive manufacturer of iPhones and iPads. However, in recent years, Apple (and other big buyers, like Amazon) have been splitting orders between Foxconn and its competitors so as to spread risk. Pegatron Corp (和碩) and Wistron Corp (緯創), both Taiwanese companies, have received big orders from Apple — and neither has an unblemished record as regards to labour issues.

Amid the rapid aging of China's population, there's a growing reluctance among the country's young people to accept factory jobs. However, the labour shortage doesn't seem to have put those who are willing to work for Foxconn in a position to bargain for better conditions. If anything, it's a factor behind some of the company's worst practices, Chan says.

Since 2010, Foxconn has boosted salaries and improved facilities in staff dormitories — but production-line workers still lack free time in which they can enjoy those amenities. Twelve-hour shifts are the norm, and it's not uncommon for workers to have just one day off in a month, says Chan, who interviewed former and current Foxconn employees in Shenzhen, Chongqing and Chengdu during extensive research trips between 2011 and 2019.

Such work rosters breach both China's labour law limits (which stipulates that overtime on top of an eight-hour shift not exceed 36 hours per month) and Apple's own Supplier Code of Conduct (which sets a maximum work week of 60 hours, and states that workers must have "at least one day off every seven days except in emergencies or unusual situations").

In Chan's opinion, one of Foxconn's most egregious practices is the recruitment of vocational-school students as "interns." She stresses that Foxconn isn't the only manufacturer doing this; Pegatron and Wistron similarly rely on interning students.

Each year, nearly 16 million student interns enrol in vocational secondary schools, according to China's Ministry of Education, and students as young as 16 temporarily join the workforce in the name of "internships."

The availability of interns weakens the bargaining position of regular employees, while making employers less inclined to take steps that might improve retention, Chan believes. She describes the use of students as "a kind of forced labour."

Completing internships is a graduation requirement for vocational-school students, but Chan has discovered that they learn next to nothing on the assembly line.

"They screw in screws or check packaging. There's no evidence of skills training. Foxconn simply wants more hands in its factory, and it treats the students as cheap, energetic and obedient labour, ignoring their educational rights as well as their labour rights. Interns tell us they're so angry about their time being wasted, and they complain about the impact working so hard has on their health," she says.

By law, interns can be paid as little as 80 percent of the company's basic wage, because their legal status is that of students, and they're assumed to be less productive than regular employees. Foxconn saves a considerable additional amount of money because there's no requirement to enrol interns in state pension and benefits schemes. What's more, interns have no right to a formal employment contract.

Since April 2016, following the implementation of China's internship regulations, Foxconn's own rules have stipulated that interns under 18 should work no more than eight hours per day, do day shifts only and work in a safe environment with proper protective gear.

"But, in reality, Foxconn violates its own regulations. Local governments compel schools to meet factories' needs. There's deep-rooted corruption and collusion," says Chan, who's interviewed local officials and teachers as well as students.

According to Chan, when Apple or other brands say they care about the freedom to associate — which is guaranteed by Apple's Supplier Code of Conduct — their words "are purely cosmetic."

VENEER OF HELPING
Independent labour organizations aren't permitted in China, and Chan does not place much hope in the country's state-sanctioned unions to protect workers' rights and interests.

"They're part of the [Chinese] Communist Party's monopoly on civil society. While some union officials advocate pro-labour legislation in an attempt to maintain social and political stability, they suppress worker self-organizations," she says.

She adds that labour rights activists and media have exposed bad practices, but Apple tells their customers and shareholders that they have a comprehensive system.

"Everything looks perfect on paper, but there's no system to collate workers' views," Chan says.

Chan and her allies in EW call for "a worker-driven mechanism through which they can communicate their demands and monitor progress," calling it "a fundamental worker-empowerment strategy."

China seems to be becoming more not less authoritarian. Acutely aware of the shrinking space for grassroots organizing, Chan believes campaigning by watchdogs like EW may offer the best hope for progress.

"Since 2015, EW has been asking public-sector entities such as universities to use their leverage to hold tech brands accountable. Our goal is to make the transnational electronics supply chain more transparent, and to give workers more dignity. Transparency means understanding working conditions, wages, training, promotion prospects," says Chan.

"I also hope global consumers — individual and institutional — will develop greater awareness. Ultimately, workers should exercise their power to unionize and bargain collectively."

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International Diary

2021

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June 16

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