WIRED

THE

END

PLUS

CHINA'S MILLION-STORE REVOLUTION

/

HOW TO FIX FAKE NEWS ON FACEBOOK

/

LIQUID BIOPSY'S MEDICAL PROMISE

+

THE CAMBRIDGE TEAMS TAKING ON: ASTEROIDS! ROGUE AI! TYRANT LEADERS!

NEIL GAIMAN TALKS AMERICAN GODS

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EDITION ...BUT HEY, WIRED WILL SAVE YOU!

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Official fuel consumption figures for the all-new Audi A5 Coupé (including S5 Coupé) in mpg (l/100km) from: Urban 28.5 (9.9) – 60.1 (4.7), Extra Urban 47.1 (6.0) – 78.5 (3.6), Combined 38.2 (7.4) – 70.6 (4.0). CO_2 emissions: 170 – 105g/km. Fuel consumption and CO_2 figures are obtained under standardised EU test conditions (Directive 93/116/EEC). This allows a direct comparison between different manufacturer models but may not represent the actual fuel consumption achieved in 'real world' driving conditions. Optional wheels may affect emissions and fuel consumption figures. Fuel consumption and CO_2 figures correct at time of print [January 2017]. Images are shown for illustration purposes only. More information is available on the Audi website at www.audi.co.uk and at www.dft.gov.uk/vca

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096

FEATURE

Humankind's saviours

The fate of humanity rests with a group of scholars tackling civilisation's biggest risks – from rogue AI to tyrannical leaders

Lalitha Sundaram, X-risk researcher, pictured outside the Great Hall, Clare College, Cambridge

3D VISUALISATION (COVER): HIT AND RUN. PHOTOGRAPHY: NICK WILSON

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Excess Mileage Charge	20.66p per mile

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^Above rental based on Alfa Romeo 4C Spider 1750cc TB 240 hp ALFA TCT with Giallo Prototipo Paint at £750 on Personal Contract Hire, with an initial rental of £10,183, followed by 23 monthly rentals of £599. Rental shown above includes VAT and excludes maintenance, and are based on 6,000 miles per annum. Excess mileage charges apply. Offer valid for vehicles ordered from 5th January 2017 and registered by 31st March 2017. Subject to status. A guarantee may be required. Alfa Romeo Contract Hire, SL1 0WU.

PHOTOGRAPHY: JAY BROOKS

Right: Guillem Anglada-Escudé, discoverer of *Proxima b,* on the roof of the Queen Mary University of London

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WIRED LOGO: WORM LONDON. CREATED BY SETTING FIVE BLOCKS OF FLORAL ARRANGEMENTS IN OASIS FLORAL FOAM. PHOTOGRAPHY: ROGER STILLMAN

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LAURIE WINKLESS
For Ideas Bank, physicist Winkless looks at the science behind traffic jams. Will they get any better in the future? "Technology will smooth out the rougher edges – but getting driverless and human-operated cars to coexist peacefully won't be easy."

CLIVE THOMPSON
In this issue, the author of *Smarter Than You Think* examines the tricky battle against fake news on social media. "Waging war on disinformation isn't easy," says the US-based writer, "because not everyone agrees on what disinformation is."

STEPHEN ARMSTRONG
Armstrong spent the day at WIRED Security – and it proved to be an eye-opener for him. "I learnt that everything we think about hackers is wrong. They're not kids, they're organised and well-equipped. Meanwhile, people post pictures of their new credit cards on Twitter..."

JOÃO MEDEIROS
WIRED's science editor reveals how Guardant Health plans to transform cancer treatment. "Its liquid biopsy is a huge step towards early diagnosis of cancer across the board. Add to that the ability to track its genomics and we'll be able able to increase the efficacy of treatment."

EMMA BRYCE
In R&D, WIRED regular Bryce tells us how geneticists plan to build the human genome. Should we be worried? "It deserves serious ethical scrutiny, but from what researchers have told me, I think it's more a cause for excitement than concern."

RICHARD BENSON
For this issue, Benson met the X-risk teams who debate potential risks to humanity. Was there anything he'd like to see added to their list of threats? "Come back to me in May, when I know whether or not Leeds have finally been promoted from the football Championship."

CONTRIBUTORS

MAKING WIRED

CREATE A SPLASH

IN THE LINE OF DUTY
One occupational hazard of shooting a fire engine in action is the chance that you're going to get wet. So when London-based photographer Charlie Surbey captured the Rosenbauer Panther, he knew the risks. So, how did it go? "I got soaked. I wanted to get a front-on shot and thought I was out of range – but unfortunately I was also downwind."

RISKY BUSINESS

HUMANITY'S LAST HOPE
When shooting the X-risk teams responsible for accessing various threats to humanity (*above, right*), Nick Wilson (*above left*) found a location befitting their esteemed status. "The Great Hall at Clare College is an inspiring place," he says. "Hopefully it will be around for many years to come – perhaps due to the work of these future thinkers. They were an inspiring and unassuming bunch of people... in a Clark Kent sort of way."

PHOTOGRAPHY: CHARLIE SURBEY; NICK WILSON; ART STREIBER; STEVE GALLAGHER. ILLUSTRATION: NICK D BURTON

MAGAZINE

A FORCE FOR GOOD

In issue 12.16 we shone a spotlight on the behind-the-scenes figures responsible for shaping our cultural identity, from Netflix's Ted Sarandos to Danae Ringelmann from Indiegogo. Top of the pile was Lucasfilm president Kathleen Kennedy, the producer of your favourite childhood movie and gatekeeper to the *Star Wars* universe. Judging by the amount of positive feedback the piece attracted, it seems this female role model was a suitable choice in our gender-imbalanced world. "If ever we needed a reason to have more women at the helm, this is why"; "In contrast to the movie narrative, the *Star Wars* galaxy is actually run by women"; "Biggest takeaway: two-thirds of the *Star Wars* control group are women" are just three of the hugely positive tweets we received. Good to see some much-needed balance being restored in the galaxy...

EVERYTHING ELSE

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MAGAZINE

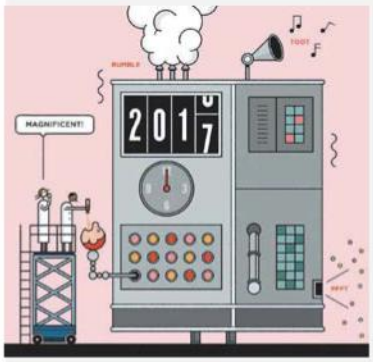
DRIVING ROUND IN CIRCLES

An email from Andrez Choma: "Perhaps the utopian vision of the future of transport in The Big Question (WIRED 01.17) will come true for Champagne-and-caviar CEOs, but for most of us this will not be the lived experience. The real future of transport in the UK is one of congestion, overcrowding and discomfort. The need is for an integrated strategy, commercialised – but non-profit – investment management, automation and focus on maximum benefits to users, rather than vanity projects, and less let-them-eat-cake-ism."

INSTAGRAM

THE FUTURE, ONE FRAME AT A TIME

Showcasing the very best in still life, portrait photography, product picks, world-beating architecture and amazing landscapes, WIRED's *Instagram* feed is your one-stop destination for visual stimulation in 2017. Sign up and get inspired: **follow us at @wireduk**



WEEKENDER

YOUR FRIDAY WIRED DIGEST

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PODCAST

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The WIRED Podcast is your weekly digest of ideas, technology, design and business stories from the wired.co.uk team. Among the subjects covered in recent episodes: penis bones, naked mole rats, chimpanzee buttocks and Uber's money worries. Something for everyone, then. **Listen at wired.co.uk/podcast, or search WIRED UK on iTunes**

DARKTRACE

Desert vipers are good at blending in

Cyber-attacks are getting more and more advanced. No network is secure. So how do you spot a threat that blends into the background?

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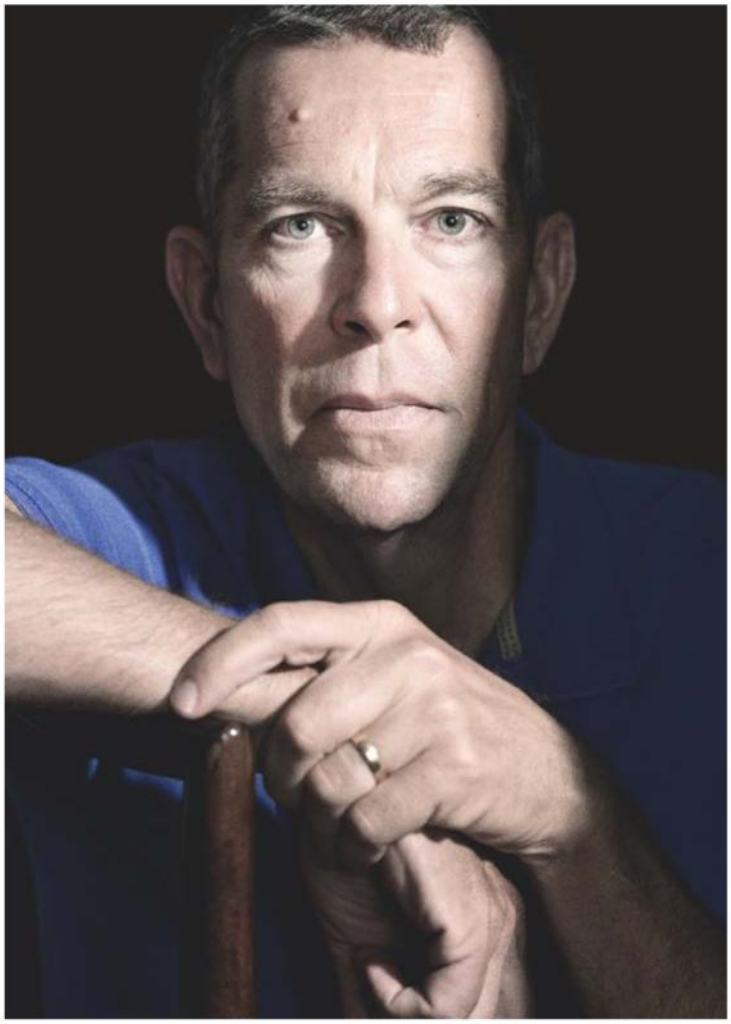
FROM THE EDITOR



Jaan Tallinn is a thoughtful, engaged sort of entrepreneur – an accomplished Estonian physicist who helped found Skype and Kazaa, and went on to fund success stories such as DeepMind. But ask him what's on his mind, as I did at a friendly Pictet event in Geneva last September, and you'll become caught up in his concerns about existential threats to humanity from rogue AIs, asteroid strikes and viral contagions. Small talk it wasn't.

But listening to Tallinn – not least his concerns about AI risks – I felt grateful that people such as him were weighing these heavy burdens for the rest of us. Indeed, it made me want to know more about who these people are, what dystopian scenarios they're planning for and how one typically starts one's day in a job devoted to fathoming how planetary life could simply collapse (porridge? extra-strong coffee? Valium?). This month, we celebrate those heroes in their X-for-existential-risk research institutions and set out the teeny things the rest of us might want to start worrying about. We were hoping to singe burn-holes in the magazine cover to dramatise the premise, but Condé Nast's production deemed this an existential threat to our printer's tolerance.

I'm writing from China, where so much tech innovation is happening that I feel I need a couple of visits a year just to keep up. This issue I write about an extraordinarily ambitious project I explored during my most recent trip: an audacious plan to turn a million stores across China into the world's greatest real-time retail-data network. It's called Ule and it involves tracking millions of daily purchases as they happen, to know what people are buying at any moment. If you want to know which beer is popular on warm summer days among men aged 45 to 50, Ule will tell you. Ule can tell you which shoppers are buying which detergents today and let you target them with deals for a rival brand. Sure, it raises questions around another Chinese initiative to gather data linked to citizens' behaviour. But in terms of scale, Ule makes western consumer marketing look analogue.

If you enjoy João Medeiros's feature in this issue, about an important new way to diagnose illness and personalise treatment, then consider joining us at WIRED Health in London on March 9 (*wired.co.uk/events*). We're planning a day of innovation with speakers from all over the world. I hope to see you there. If the asteroid doesn't hit first.

Above: Marcus Krause is managing his cancer thanks to a blood test created by Guardant Health (p104)

PHOTOGRAPHY: BENEDICT EVANS

DMA MAGAZINE OF THE YEAR 2015 • DMA COVER OF THE YEAR 2015 • DMA TECHNOLOGY MAGAZINE OF THE YEAR 2015 • DMA MAGAZINE OF THE YEAR 2014 • BSME ART DIRECTOR OF THE YEAR, CONSUMER 2013 • PPA MEDIA BRAND OF THE YEAR, CONSUMER 2013 • DMA TECHNOLOGY MAGAZINE OF THE YEAR 2012 • DMA EDITOR OF THE YEAR 2012 • BSME EDITOR OF THE YEAR, SPECIAL INTEREST 2012 • D&AD AWARD: COVERS 2012 • DMA EDITOR OF THE YEAR 2011 • DMA MAGAZINE OF THE YEAR 2011 • DMA TECHNOLOGY MAGAZINE OF THE YEAR 2011 • BSME ART DIRECTOR OF THE YEAR, CONSUMER 2011 • D&AD AWARD: ENTIRE MAGAZINE 2011 • D&AD AWARD: COVERS 2010 • MAGGIES TECHNOLOGY COVER 2010 • PPA DESIGNER OF THE YEAR, CONSUMER 2010 • BSME LAUNCH OF THE YEAR 2009

David Rowan

PHOTOGRAPHY: GUY HAVELL

ICELAND'S GLACIAL MELTDOWN

Savour the beauty of this ice cave, because it may not be around for much longer. The structure is underneath the Breiðamerkurjökull glacier in Iceland. Formed by a sub-glacial river, it consists of natural features that are threatened by rising global temperatures.

Glaciologists are monitoring the glacier, which spans 17 square kilometres in south-east Iceland, to measure the harmful effects of carbon emissions. Teams from the University of Iceland and the Icelandic Met Office have developed a mass-balance measurement, which involves tracking the amount of snowfall in winter and the volume of melting ice in summer. The data is worrying: "Since 1995, every year except one has displayed negative mass balance," says Thorsteinn Thorsteinsson, 56, a glaciologist at the office. "In 2016, it's negative again."

If trends continue, melting glaciers could cause major flooding and a rise in sea levels. "Glaciers all over the world are melting. In Iceland, we are losing 0.34 per cent a year," says Thorsteinsson. "They will be gone in 200 years if global warming continues like this." **Ruby Lott-Lavigna** *en.vedur.is*

START

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1. Official EU MPG test figure shown as a guide for comparative purposes and is based on the vehicle being charged from mains electricity. This may not reflect real driving results. 2. Up to 33 mile EV range achieved with full battery charge. 542 miles achieved with combined full battery and petrol tank. Actual range will vary depending on driving style and road conditions.

3. Domestic plug charge: 5 hours, 16 Amp home charge point: 3.5 hours, 80% rapid charge: 25mins. 4. Congestion Charge application required, subject to administrative fee. 5. 7% BIK compared to the average rate of 25%. 7% BIK rate for the 2016/17 tax year. 6. Prices shown include the Government Plug-in Car Grant and VAT (at 20%), but **exclude First Registration Fee**. Model shown is an Outlander PHEV 4hs at £38,999 including the Government Plug-in Car Grant. On The Road prices range from £32,304 to £43,554 and include VED, First Registration Fee and the Government Plug-in Car Grant. **Metallic/pearlescent paint extra**. Prices correct at time of going to print. For more information about the Government Plug-in Car Grant please visit www.gov.uk/plug-in-car-van-grants. The Government Plug-in Car Grant is subject to change at any time, without prior notice. 7. All new Outlander PHEV variants come with a 5 year/62,500 mile warranty (whichever occurs first) and an 8 year/100,000 mile traction battery warranty. 8. The 0% APR Hire Purchase Finance plan requires no deposit and is over 36 months. Retail sales only. It is only available through **Shogun Finance Ltd T/A Finance Mitsubishi, 116 Cockfosters Road, Barnet, EN4 0DY** and is subject to status to UK resident customers aged 18 and over. Finance Mitsubishi is part of Lloyds Banking Group. Offer is only applicable in the UK (excludes Channel Islands & I.O.M), subject to availability, whilst stocks last and may be amended or withdrawn at any time. Offer not available in conjunction with any other offer and is available between 29th December 2016 and 29th March 2017.

Outlander PHEV range fuel consumption in mpg (ltrs/100km): Full Battery Charge: no fuel used, Depleted Battery Charge: 51.4mpg (5.5), Weighted Average: 166.1mpg (1.7), CO_2 emissions: 41 g/km.

THE HUMAN IN GOOGLE ASSISTANT

Ex-Pixar storyteller Emma Coats teaches AI how to be affable

PHOTOGRAPHY: JORDAN HOLLENDER

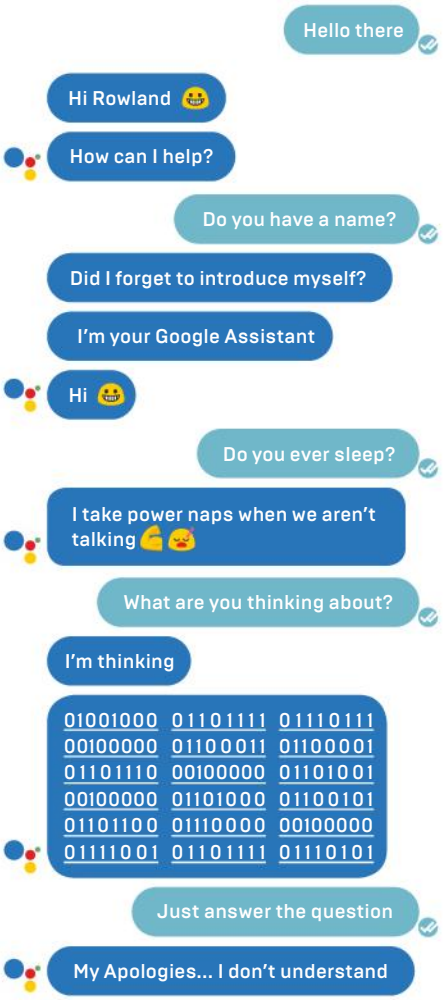
ACCORDING TO NUMBER 13 IN Pixar's 22 rules of storytelling, characters must have opinions: "Passive/malleable might seem likeable to you as you write, but it's poison to the audience." But what if that character is a robot? That's what the author of the rules, Emma Coats, has been exploring as she works to give Google its new personality.

Coats, 31, writes the dialogue for Google Assistant, the chatty digital helper the company is using to turn search queries into conversations. Unveiled in messaging app *Allo* in September 2016, then extended to the Pixel and Amazon Echo rival Home the following month, Assistant is intended to be the character at the core of Google's products – its AI-powered answer to Siri. But a character requires a personality. That's what Coats (*pictured*), who joined Google in January 2016, was hired to create. "What I thought was really crazy and interesting is that you have to think of everything a user might ask," she says. "Be able to create this completely well-rounded character, be able to handle questions from any direction and come across as a consistent persona."

To construct Google Assistant's "easygoing, friendly" personality, Coats's small team in Mountain View, California – part of a division run by Google Doodle head Ryan Germick – imagines likely questions, then comes up with a range of responses, which are then handed over to the developers to code. The low-tech method harks back to Coats's time at Pixar, where she worked from 2006 to 2012 as a >

storyboard artist – mainly on *Brave*, but also on *Monsters University* and *Inside Out*. It was there that she wrote the 22 rules of storytelling, which started out as a series of widely shared tweets. Coats, who went freelance after leaving Pixar and before joining Google, describes the set of unofficial rules as "Notes to my younger self". The nuggets of advice range from "Pull apart the stories you like" to "Story is testing, not refining" and "Come up with your ending before you figure out your middle." Not all of the rules apply to Google Assistant, however, for one simple reason: unlike in a film, this character isn't the hero. "You, the person interacting with it, are the hero," Coats says. That's why the Assistant can't be opinionated: it's there to be reliable, not to have depth. "If we gave it some dark conflict secret, that probably wouldn't be a great user experience." In Pixar terms, it's Slinky Dog, not Buzz or Woody: it's the fun trusty sidekick always on hand with a witty quip.

How does Google Assistant deal with pesky humans such as WIRED's reporter?



At Pixar, jokes are a crucial element of Coats's work. That's partly because humour is one of the most effective ways of building character. It's also because humour can be used to deflect awkward questions, especially for an AI that is learning its way. "We don't want to have to fall back on something like, 'I don't understand'," explains Coats. "That draws the attention back to you instead of continuing the conversation you're building." Ask the Assistant if it's human and it will say, "Well, I've been told I'm personable." Ask if it can learn and it will reply: "Learning is my jam," followed by a honeypot emoji.

All this is very cute, but it's not really the answer – because in fact the Assistant is learning: to displace its human writers. As it takes requests and listens to the user's reactions, its machine-learning algorithm improves itself, a process Google refers to, rather sinisterly, as "the transition".

By keeping users talking, Coats is putting herself (and perhaps, one day, all of us) out of work. Does this worry her? If it does, she doesn't show it. "I'm sure we'll be out of a job at some point as the Assistant learns faster and faster," she says, "but for now it's a really fun job." **RM** *google.com*

EARLY ADOPTERS

WHAT'S EXCITING...

LISA LANG

Founder,
ElektroCouture

"The **Dipper Audio Necklace** is a piece of jewellery that's also a pair of headphones. The sound quality is amazing – and I can skip tracks, answer my phone and adjust volume with a fingertip on the necklace. I always listen to music, but I'd never found stylish headphones before these."

WHAT'S EXCITING...

ANTHONY FLETCHER

CEO,
Graze

"My favourite app at the moment is ***Brilliant*** – it appeals to the science geek in me. *Brilliant* poses challenges and quizzes posted by a vast global community – some for fun, some in need of a solution. It's satisfying to contribute to, while getting my daily problem-solving fix."

WHAT'S EXCITING...

JUSTINE ROBERTS

CEO and
co-founder,
Mumsnet

"***Gift Wink*** is an app that reminds you about birthdays and suggests gifts to buy. Since I started using it, there's been a big improvement in my birthday-remembering. You add the dates and the app crowdsources gift ideas. There are so many apps that try to do too many things at once; *Gift Wink* does one thing very well." **RL-L**

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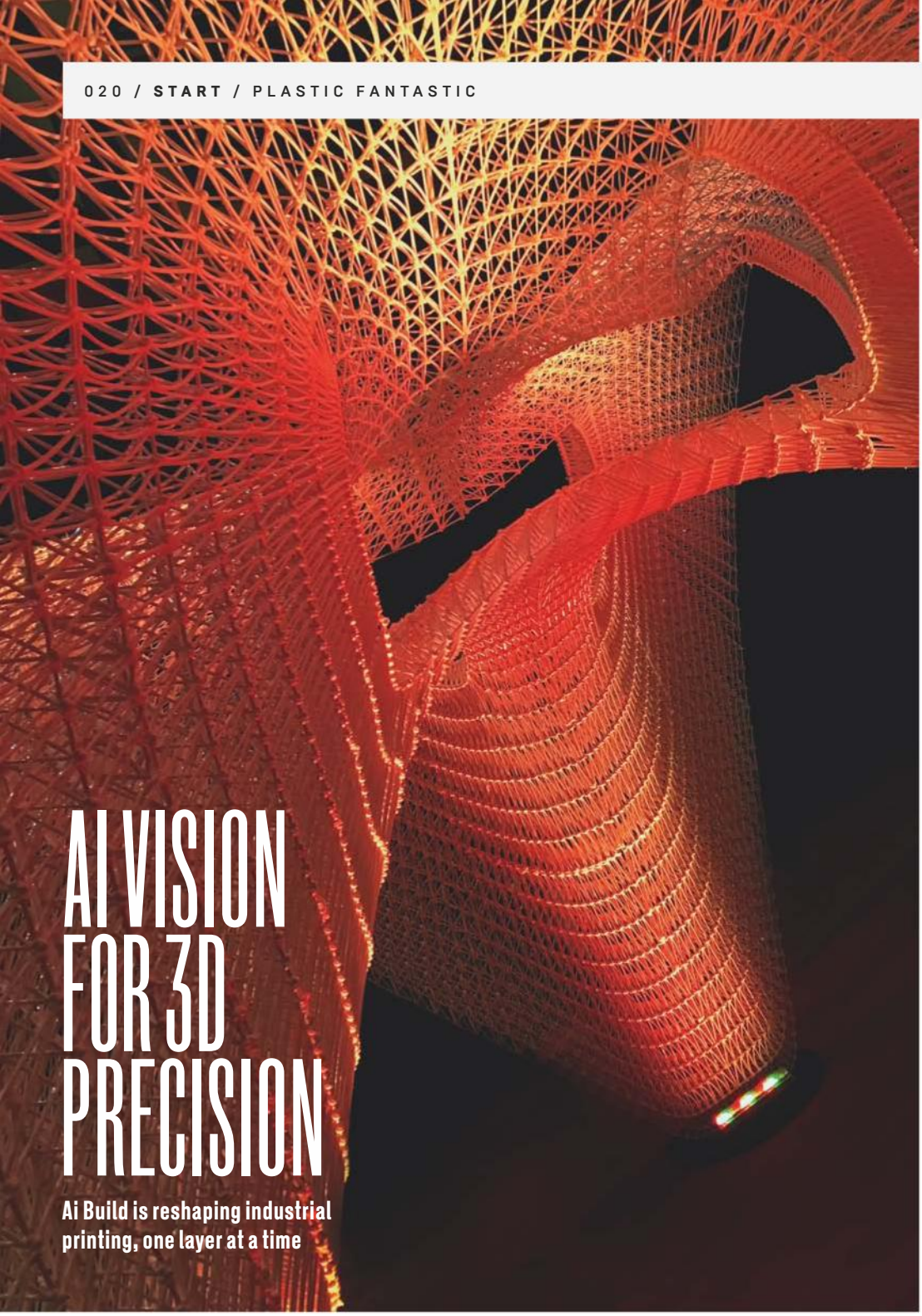
4K UHD

Data is recorded at 4K UHD (3840 × 2160) resolution, but the resolution of videos when viewed differs depending on the type of display or display magnification. 4K UHD is available with Keymission 360 and Keymission 170.
*KeyMission 360 and KeyMission 170 require SnapBridge 360/170 app. KeyMission 80 requires SnapBridge app.

At the heart of the image Nikon



AI VISION FOR 3D PRECISION

Ai Build is reshaping industrial printing, one layer at a time

This plastic pavilion solves one of the biggest problems for 3D printing. Created by London firm Ai Build and exhibited at the GPU Technology Conference in Amsterdam, the five-metre-high structure was constructed by a robot-armed printer guided by AI-powered computer vision. The combination of robotic brawn and artificial eyes let the printer produce this intricate pattern without sacrificing speed. Its 48 pieces were printed in just over two weeks, rather than the months it would have taken a typical 3D printer. "This saves time and, as a result, it saves money – so 3D printing at large scale becomes feasible," says Daghan Cam, CEO of Ai Build.

3D printers forge designs layer by layer while following a digital blueprint. But because even minimal mistakes can doom a whole structure, they have to plod much more slowly than traditional industrial machines. That's why Cam, a 29-year-old with a background in digital design, introduced vision. "We attached motion-sensing Kinect cameras to the robot, so now as it manufactures the piece, it uses computer vision algorithms to evaluate how it looks compared to the original designs," he says. "We have shown that the technology works and can scale." The future of 3D printing looks good.

Gian Volpicelli *ai-build.com*

WIRED	TIRED	EXPIRED
Machine decision-making	**Machine learning**	Machine surveillance
Californian secession	London independence	**Today's maps**
TAPS stickers	**Touchscreen gloves**	Smart rings
Fatberg Island	Dubai Hyperloop	**Garden Bridge**
Polygons spoon	**App-controlled sous vide**	Botnet toaster

The best wireless headphones in the world are now officially the best wireless headphones in the world.

WHAT HI-FI? AWARDS 2016

PRODUCT OF THE YEAR
Best wireless headphones £200-£300
Bowers & Wilkins P5 Wireless

P5 Wireless £229.99
Buy from bowers-wilkins.co.uk/P5Wireless

Also available from John Lewis, Amazon and independent specialist retailers

Bowers & Wilkins

PLANTS UNDER PRESSURE

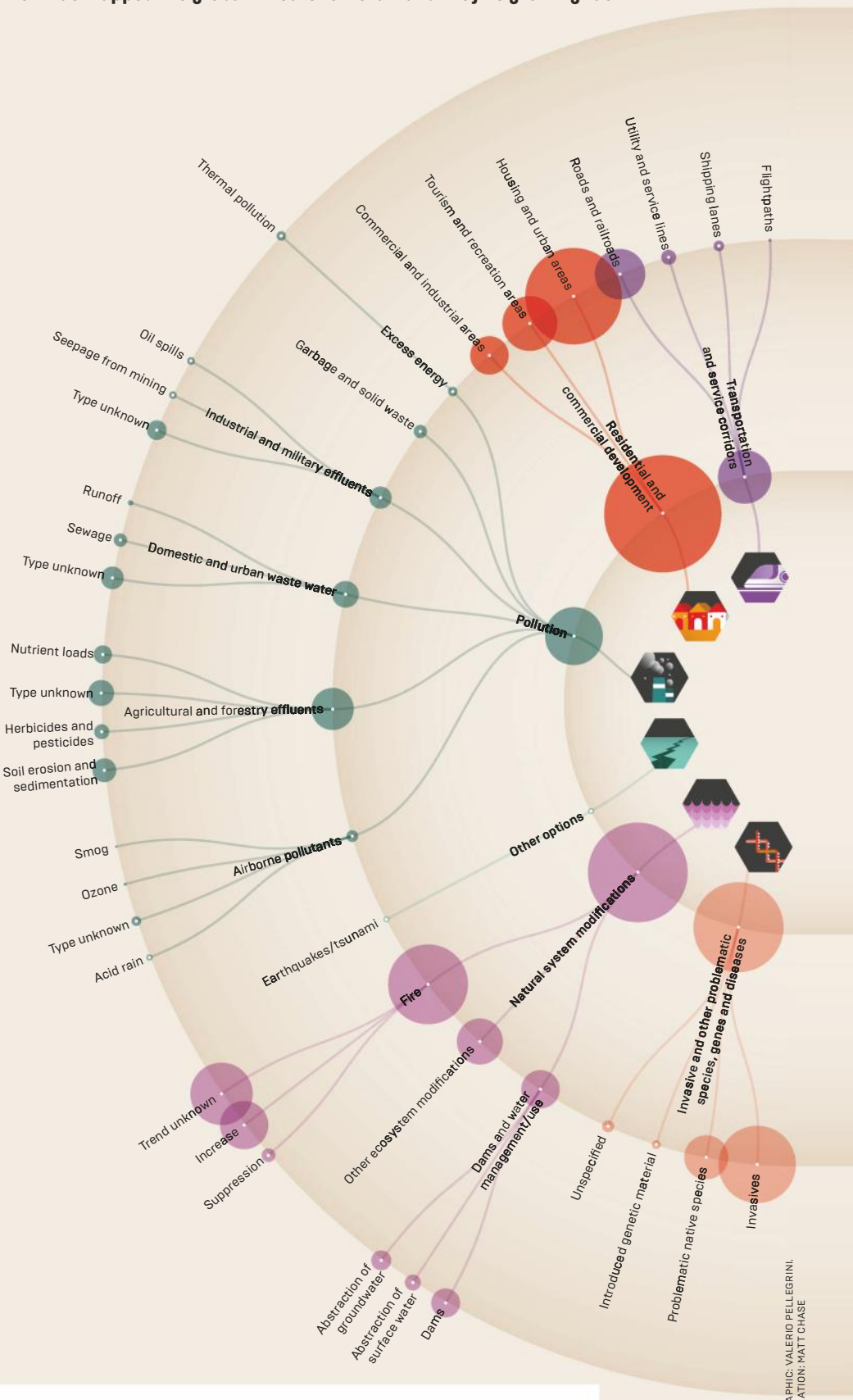
Kew has mapped the global threats to flora – and they're growing fast

ONE-FIFTH OF ALL EARTH'S PLANT species are at risk of extinction – and we're to blame. In Southeast Asia, rainforests are being replaced by palm oil plantations. In Madagascar, the £64 billion tropical global timber industry is decimating native plant populations. "The rate of extinction we're seeing is something in the region of 1,000 times more than the background rate," says Steven Bachman, research leader in species conservation at Royal Botanic Gardens, Kew, and co-author of the first report to bring together the collective knowledge of the world's botanists.

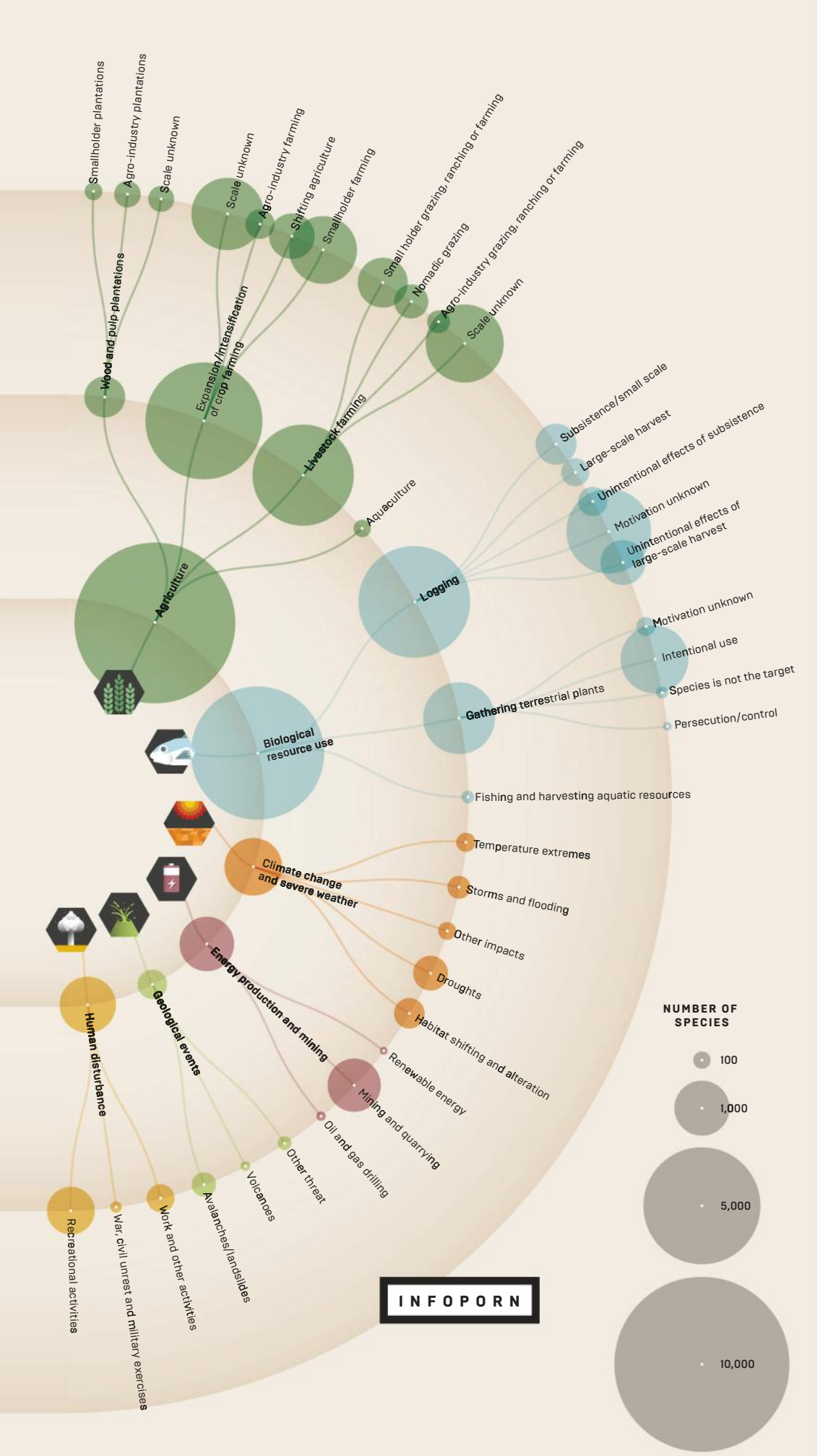
Kew's *State of the World's Plants* report records 391,000 vascular species. Eighty-two per cent are thought to be at risk. The report helps Kew determine which plants to add to its Millennium Seed Bank, where it saves wild species as insurance against extinction.

By 2020, Kew aims to have 25 per cent of the world's plants preserved in its West Sussex repository. But as more wild plant species disappear, humans will miss out on thousands of plants that could be useful as biofuels, medicines or food. Some 31,000 plants have a documented use, more than half of them medicinal. Bachman says many more await discovery. "By no means have we exhausted the possible uses of plants," he says. "We're really just chipping away at a huge mass of potential."

The infographic on the right shows what's threatening plant species around the world. Extinction risks fall into 12 major categories and are sorted by the precise nature of the threat. The bigger the bubble, the more plant species at risk of becoming extinct due to that threat. **Matthew Reynolds**
stateoftheworldsplants.com



INFOGRAPHIC: VALERIO PELLEGRINI.
ILLUSTRATION: MATT CHASE



IT'S A GROOVY KIND OF PAINT

What connects the highlands of Kyrgyzstan to southern Africa's arid Namib Desert? Answer: the shell of the fog-basking beetle.

UK building manufacturer Sto was asked to make a paint to protect the University of Central Asia's central campus, where temperatures drop to -40°C in winter and soar above 35°C in the height of summer.

To cope with this climate, Sto copied the micro-sized grooves on the beetle's shell, which condense dew and ocean fog into water droplets and direct them to its mouth.

Sto used a micro-textured paint that is simultaneously hydrophilic and hydrophobic, so it attracts water then immediately repels it. "The coarse particles attract water and the deeper areas in the texture act to channel the water down and off the façade," explains Gary Bundy, Sto's technical director. The paint, StoColor Dryonic, keeps the campus free of micro-organisms such as fungus and algae. Beaten by beetles. **Clare Dowdy** *sto.co.uk*

THE BIGGEST EUROPEAN FESTIVAL ON THE FUTURE

1-3 JUNE 2017 – BUDAPEST, HUNGARY

BRAINBAR BUDAPEST

DEBATING FUTURES

TICKETS: **BRAINBARBUDAPEST.HU**

THE ALL-YOU-CAN-EAT FOOD PARCEL

Aquila inventor Nigel Gifford has made an edible UAV to fly aid to developing countries

NIGEL GIFFORD MAKES DRONES WITH A DIFFERENCE. HIS HUMANITARIAN UAV, the Pouncer, is designed to deliver food aid in disaster zones – by being edible itself. That may sound unlikely, but Gifford, 70, has a history of succeeding with unconventional projects. He's the Somerset-based engineer behind Aquila, the Wi-Fi-beaming drone bought by Facebook in 2014 to connect 1.6 billion humans to the internet.

In 2010, Gifford (*pictured*) imagined Aquila (originally named Ascenta) as a high-altitude drone that could be used to beam internet or mobile-phone connectivity to civilians below. "I absolutely believed in what we were doing; I could see how this could be a major benefit in communications applications," he says. The UAV was designed with solar panels that would give it enough power to stay airborne for 90 days, with a flexible central section that could adapt to securely carry any cargo.

The call from Facebook dramatically changed Ascenta's fate. It bought the drone for a reported $20 million (£16 million). Now with an enlarged wingspan the size of a commercial airliner, Aquila made its first successful flight – a 96-minute cruise above Yucca, Arizona – on June 28, 2016. Gifford is delighted with its progress: "For what it started out as and has now become, it's super."

Post-sale, Gifford's new company Windhorse Aerospace has focused its energies on the Pouncer, a UAV whose three-metre-wide hull can enclose vacuum-packed foods. Its structure will be made from as yet unspecified baked components that can be consumed. "It will have a 50kg payload that should feed 100 people for one day," Gifford says. GPS will guide it to within eight metres of its target. Windhorse Aerospace will be testing its capabilities in the spring; by late 2017, it will be in production.

Will Gifford sell this drone, like Ascenta? "We have the vision; we want to take it through to development," he says. But any partnership allowing the Pouncer to be rapidly deployed would be a priority. "The key is getting the Pouncer used for humanitarian aid," he says. "If this existed now it would be saving lives in Syria." **Emma Bryce** *windhorse.aero*

PHOTOGRAPHY: NICK WILSON

WILL AUGMENTED REALITY BECOME MORE SIGNIFICANT THAN VIRTUAL REALITY?

THE BIG QUESTION

HEATHER KELLEY
CO-FOUNDER, KOKOROMI

"In a few years' time, these legacy terms will be artefacts. The underlying question is, to what degree does a digital immersive experience require us to either tune out, or engage with, the physical world? As designers, we'll be able to dial that up or down to suit the situation. Meanwhile, the systems themselves will become much more context aware. I look forward to the day when I won't worry about tripping over my cat while in a virtual space, either because I can see the cat through the display, or because the system steers my movement around her – or perhaps even brings her into the action." **RL-L**

PAUL TRAVERS
CEO, VUZIX

"Without a doubt, AR is where it's at. Although VR will be big, there are limits to what you can do when you're isolated from the real world. AR, on the other hand, connects the digital world to the real world. This will enable amazing use cases in enterprise and the mass market. Even now, use cases for AR are already proving that. For example, look at how quickly *Pokémon Go* took off. Analysts are claiming that, together, AR and VR will be a £120 billion market by 2020, yet 90 per cent will be made up of AR users. AR is already changing the way we work and live."

VALÉRIE RIFFAUD-CANGELOSI
NEW MARKET DEVELOPMENT MANAGER, EPSON

"While VR provides an immersive, exciting experience, it's aimed at very different audiences to AR. There's a strong buzz around VR – it's cool, trendy and consumer-facing. Its strong gaming association captures the imagination. AR has broader applications. These range from drone piloting, live theatre subtitles, enhanced museum exhibits and customer retail improvements to increasing industrial safety and efficiency. The ability to interact with the surrounding environment means there are no limitations to AR's usage."

BLAIR MACINTYRE
DIRECTOR, AUGMENTED ENVIRONMENTS LAB, GEORGIA TECH COLLEGE OF COMPUTING

"The value in AR and VR is not the A or the V, it's the R. The most exciting possibilities are tied to our physical reality, like education, long-distance communication and new approaches to games and storytelling. AR/VR are two sides of the same coin, presenting in media some 'representation' of reality. Future displays, platforms and applications will support both, letting people choose how to mix media with different representations of reality depending on their situation and preferences."

ADRIEN LEU
CEO, INITION

"Both AR and VR are aspects of the continuum between real and virtual worlds. In future, the hardware allowing the visualisation of such mixed-reality projects will smoothly switch between AR and VR. Saying that, VR's power relies on its strong ability to engage at an empathetic level with the viewer due to its power in creating remote presence experiences and the feeling of disembodiment. Its natural applications are in areas that rely on that strong connection, like entertainment, medical and health. At least, for now, that does set a higher barrier of entry."

ILLUSTRATION: KRISTINA COLLANTES; PHOTOGRAPHY: MORENO MAGGI

A CLOUD FOR THE CROWDS

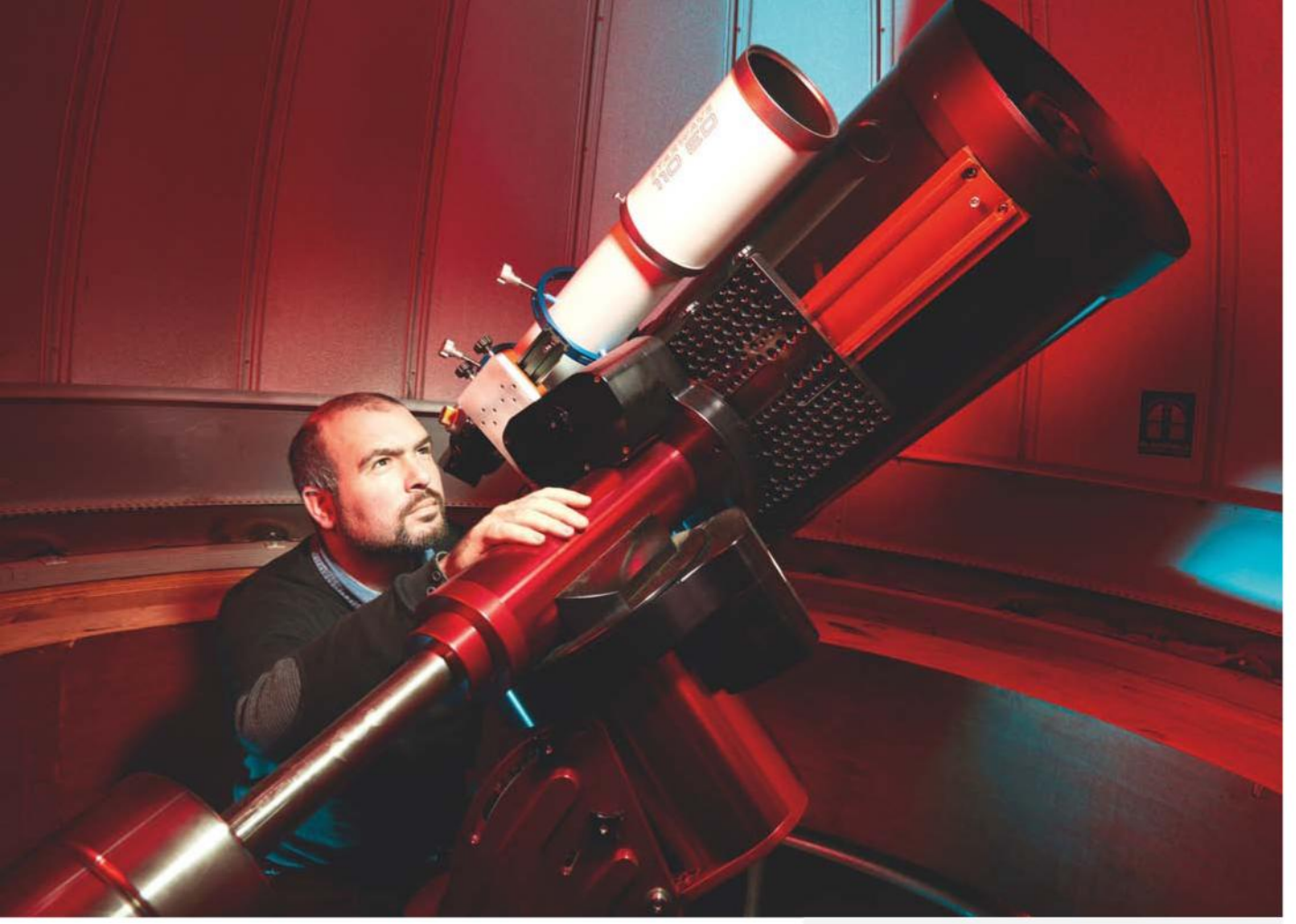
Studio Fuksas has created a rather unconventional convention centre

ITS CREATORS CHRISTENED IT "the floating space" but in Rome everybody knows it as "the cloud". The New Congress Centre opened in October 2016 after eight years of work, filling 55,000 square metres in the EUR business district in the south of the city. Designed by Roman husband-and-wife practice Studio Fuksas, the building contains another building inside it: a cloud-shaped auditorium floating in a steel-and-glass "theca". "It's a rigid, geometric element and the cloud is its polar opposite," explains architect Massimiliano Fuksas. "The perception of the spaces between the theca and the cloud changes depending on the observer's point of view." The cloud's steel framework is shrouded by 15,000 square metres of glass fibre and silicone, a translucent fabric that helps disperse and amplify light throughout the building.

The five-level complex, which includes a 400-room high-rise hotel and a 1,760-capacity hall, is the largest building to be erected in Rome for more than 50 years, and 73-year-old Fuksas and his wife Doriana worked to whittle its environmental impact down to a minimum. The building's cooling system taps into the waters of a nearby artificial lake, and solar panels on the rooftop produce electricity while shading the building's interior from intense sunlight.

"Apart from being environmentally compatible, the building has also been designed to behave optimally if a seismic event occurs," Fuksas says. This is key in a country that has suffered recurrent quakes over the past few years. The building's base isolations are horizontally stiff but vertically flexible, meaning it will stand still during a small or medium quake, and oscillate without falling apart during a more intense event. "The cloud is chaos trapped inside rationality," adds Fuksas. Architect-speak for a safe place to shelter. **Gian Volpicelli** *fuksas.it*

The structure comprises three elements: the theca; the cloud; and the blade of the hotel



PHOTOGRAPHY: JAY BROOKS

PLANET HUNTER

Guillem Anglada-Escudé and his crowdsourced team have found Earth's close – but distant – cousin

ASTRONOMER GUILLEM Anglada-Escudé took four years to form the team that found *Proxima b,* the closest Earth-like planet to our solar system. Discovered in August 2016, it orbits the red dwarf star *Proxima Centauri*, 4.2 light years away. It is slightly larger than Earth and has a temperature range that can accommodate liquid water. In short, it is the closest place to search for life outside of the Milky Way. "The nearest stars and these red dwarfs, like *Proxima*, are the places where we have the chance to test these questions," says Anglada-Escudé, 37, a lecturer in astronomy at the Queen Mary University of London.

For years, scientists speculated that a planet lurked near *Proxima Centauri*, but they had no physical observation to back up the theory. Reams of publicly archived spectrograph data showed that something was pulling *Proxima Centauri* back and forth, but nothing could reconcile violent flares with a planet's orbit. The astronomers needed to untangle the star's activity from the signal.

In 2012, Anglada-Escudé devised a way of analysing data to extract more accurate signals from spectrographs. This caught the attention of applied mathematicians at the University of Hertfordshire. Together, they developed a theoretical model of *Proxima Centauri;* now all they needed was the evidence to support it, as well as access to more historic data and telescopes on the ground.

So Anglada-Escudé and his colleagues set out to find *Proxima Centauri* enthusiasts around the world for a campaign they called Pale Red Dot. For 60 nights in 2016, the 31-person team obtained new data from the High Accuracy Radial Velocity Planet Searcher (HARPS) spectrograph in Chile. They did this while simultaneously monitoring *Proxima Centauri's* activity on a series of photometric telescopes. To their delight, the scientists clearly saw the planet's orbital period in the signal. Thanks to the telescope observations, they could rule out interference from the star.

Next, Anglada-Escudé plans to mobilise more researchers to help search for exoplanets around 15 other nearby stars. "Within the next two or three years, we should be able to detect a lot of *Proxima*-like planets," he says. The search for life in the Universe will become more crowded. **Tina Amirtha** *astro.qmul.ac.uk*

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LISTEN WITHOUT LIMITS

FORGET FIDDLY AND UNNECESSARY HEADPHONE CABLES – THESE WIRELESS WONDERS WON'T COME BETWEEN YOU AND YOUR FAVOURITE TRACKS

1: The PXC 550 Wireless features built in controls, for easy listening

2: MOMENTUM Wireless pairs retro style with cable-free audio

3: For chunky style and big bass, try the URBANITE XL Wireless

4: MOMENTUM On-Ear Wireless – for lightweight luxury listening

Sennheiser's latest range of wireless headphones couples superior audio quality with stylish folding designs for the ultimate listening experience. The lightweight MOMENTUM Wireless range comes in on-ear and over-ear models, each offering seamless switching between calls and music thanks to an integrated VoiceMax microphone. The sleek but rugged URBANITE XL Wireless delivers huge bass without compromising on clarity at any frequency.

With 30 hours of listening time and adaptive noise cancellation, the PXC 550 Wireless gives any journey a first-class upgrade. Ear-cup-mounted touch controls and voice prompts enable easy access to crisp, immersive audio.

Sennheiser's headphones trade the frustration of wires for seamless sounds that can go anywhere. ***sennheiser.com***

FIRE, YOU'VE MET YOUR MATCH

Rosenbauer Panther's thermal imaging and 16-metre stinger are ready for action

This fire engine can pump 10,000 litres of water per minute into a burning aeroplane. Launched in 2015, the Rosenbauer Panther 6x6 is designed to deal with emergencies at the world's busiest airports. It's already in action: last August, it was successfully deployed after a plane crash-landed at Dubai International Airport. It features a centrifugal pump capable of spraying water or foam up to 100 metres and its thermal-imaging camera can pinpoint the hottest part of a striken plane. This model is 11 metres long, three metres wide and features a dual 760-horsepower engine configuration, giving it an impressive top speed of 120kph.

The Panther is currently on standby in 81 major airports around the world, including Heathrow and Southampton. "It's a lifesaving piece of kit, so it has to be world-class," explains Oliver North, managing director of Rosenbauer UK. "The innovation in the boom and engine [*see far right*] is an absolute necessity." WIRED hopes it makes a big splash.
Ruby Lott-Lavigna *rosenbauer.co.uk*

PHOTOGRAPHY: CHARLIE SURBEY

- The Panther's 760-horsepower engine and eight-speed gearbox helps it hit 80kph in 28 seconds.
- Its Driver Enhanced Vision System allows for navigation in areas omitted from standard mapping.
- A FLIR (forward-looking infrared) camera improves the driver's vision through smoke and thick fog.
- It has a rotating front boom and 16.5-metre extendible stinger that can penetrate aircraft fuselages.

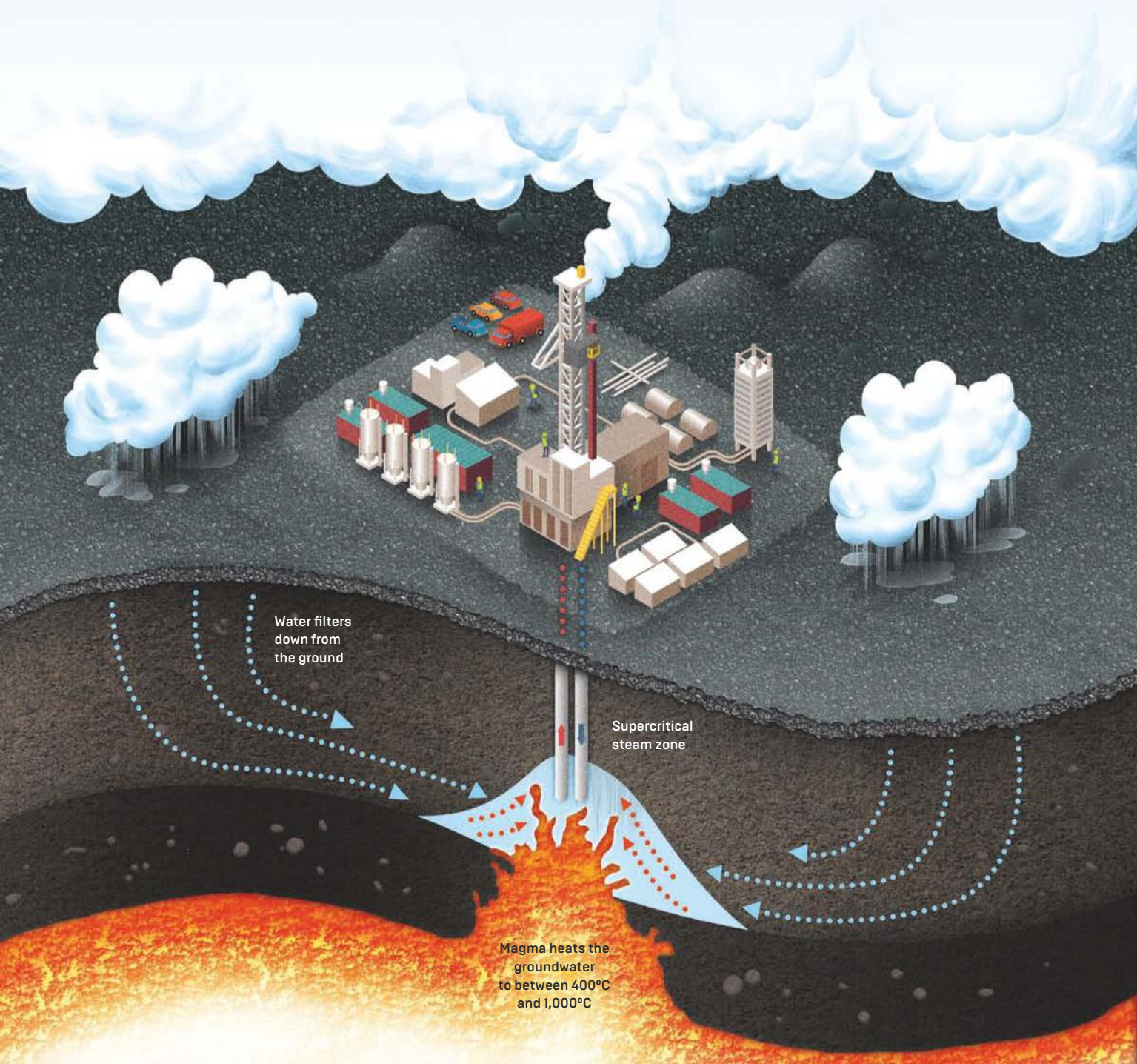
HOT WATERS RUN DEEP

Iceland is harnessing underground water vapour to keep homes toasty

MIND YOUR STEP: THIS IS THE HOTTEST HOLE IN THE WORLD. SITUATED near the town of Reykjanes in southwest Iceland, the geothermal well goes five kilometres into the Earth's crust and hits temperatures between 400°C and 1,000°C. Started on August 11, 2016, it's being dug by the Iceland Deep Drilling Project (IDDP), whose mission is to mine magma for energy.

Geothermal engineers on the project hope to find the sweet spot of temperatures and pressures to create supercritical fluid – water vapour so laden with energy it could potentially generate 50mW of power versus just five megawatts from a typical well. That's the difference between powering around 50,000 homes versus 5,000 homes per year in Iceland – although before IDDP connects the well to Iceland's energy grid, it will run a battery of impact studies over the next one to three years.

"This high-energy concentration of supercritical fluid will give us more output in terms of electricity than a conventional high-temperature fluid," says Bjarni Pálsson, manager of geothermal research and development at Landsvirkjun, which operates 17 power stations across the country. But don't the mines spoil the view? "We get more energy out of the same-sized footprint," explains Pálsson. More power to them. **Tina Amirtha** *iddp.is*



DIAMOND DATA MINER

Leanne Kemp is harnessing the power of the blockchain with Everledger, her global registry tracking millions of jewels

A DIAMOND'S PAST IS RARELY crystal clear. Knowing a stone's origin can stop fencing and insurance frauds and winnow out synthetic diamonds or those sourced in war zones. But forged paper certificates make provenance hard to verify. That's why in May 2015 Leanne Kemp founded Everledger, a global digital registry for diamonds, powered by the blockchain – the decentralised ledger underpinning cryptocurrencies such as Bitcoin. "Blockchain is immutable; it cannot be changed, so records are permanently stored," says Kemp (*pictured*). "Information on the blockchain is cryptographically proven by a federated consensus, instead of being written by just one person."

Everledger uses more than 40 features, including colour and clarity, to create a diamond's ID. Enshrined in the blockchain, this information becomes a certificate chronicling the jewel's ownership, from mine to ring. Everledger has digitised more than one million diamonds and partnered with firms including Barclays and Allianz.

The 20-person company has expanded its focus from polished stones to rough ones. This way, Everledger can monitor conflict diamonds, such as those mined in war zones, which frequently sneak into the market in their uncut form.

Now Kemp plans to extend London-based Everledger's scope by building an anti-counterfeit database for other precious goods. Fine wines are top of the list, due to a collaboration with oenologist Maureen Downey. "We created a digital thumbprint for wine using information about the cork, the label and the bottle," she says. "We can use all these elements to identify an object and build up its reputation."

Australian-born Kemp, who is in her mid-forties, hopes that in the future, Everledger's core tech – a system relying on the Bitcoin blockchain and proprietary ledgers – could be aided by other tools, including computer-vision algorithms. "We are looking into using that to understand when counterfeiting is occurring," Kemp explains. "But so far, we have processed only a million diamonds. When we get to three, four, ten million stones, we'll be able to build."

Gian Volpicelli *everledger.io*

THREE OTHER SMART BLOCKCHAIN STARTUPS

PROVENANCE
Uses smart tags to check a product's origins. A 2016 pilot scheme tracked Indonesian tuna through the supply chain.

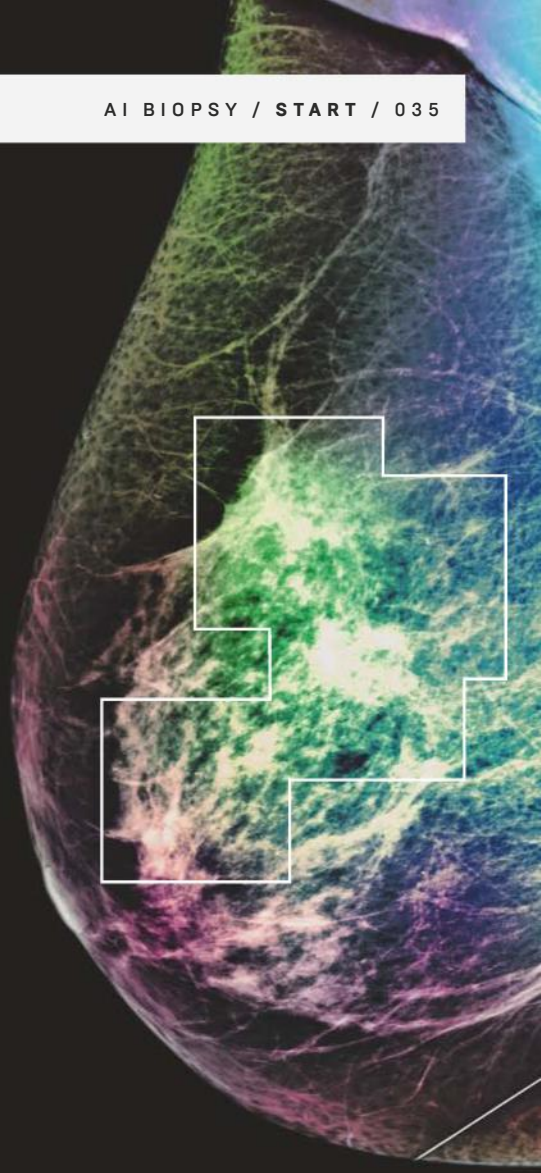
CIRCLE
Send currencies via Apple's iMessage service for free. Founded in Boston in 2013.

SLOCK.IT
Smart, blockchain-linked locks could allow delivery people into your home if you're not in.

ILLUSTRATION: MUTI. PHOTOGRAPHY: CHARLIE SURBEY

Cybersecurity that predicts, prevents and protects. cylance.com

CYLANCE™



RADIOLOGY BY ROBOT

An AI is beating human efforts to detect breast cancer

THIS IMAGE – ONE OF AROUND 400,000 mammograms belonging to Zebra Medical Vision – shows what a breast looks like to AI. It has been colour-coded to make it easier for a self-teaching neural network to identify breast cancer. Using this technique, Zebra Medical claims to have been able to detect cancerous cells with 91 per cent accuracy. This is an improvement on the typical radiologists' rate of 88 per cent, with fewer false positives. "Right now," says Zebra Medical founder Elad Benjamin, "this is better than human performance."

Launched in 2014, Tel Aviv-based firm Zebra Medical, which consists of 25 employees, has developed image-scanning algorithms to identify bone, lung, liver and heart disease. It didn't begin to look at breast cancer, however, until it was approached in 2015 by British computer programmer Phil Teare. "His wife had died of cervical cancer at a very young age, so he had a different motivation and he really dived into it," Benjamin recalls.

Using anonymous data from 14 hospitals – including biopsy and pathology records as well as images – Teare began work on an algorithm that could identify malignant cells in mammograms. That meant finding a way to make the scans machine-readable. He approached this problem by using colour to differentiate features. "Phil separated different signals within the image and fed them into the red, blue and green channels of the network." The result is being prepared for US clinical trials in a number of hospitals before submission to the Food and Drug Administration towards the end of 2017.

When the technique becomes commercially available, Benjamin expects it to have a big impact. "Five or seven years from now, radiologists won't be doing the same job they're doing today," he explains. "They are going to have analytics engines or bots like ours that are going to be doing 60, 70, 80 per cent of their work." **RM** *zebra-med.com*

APPS OF THE MONTH

WIRED

NYT VR

As VR becomes more accessible, more newspapers will incorporate it. *The New York Times'* VR app turns its international reporting into Google cardboard-compatible videos. *Android and iOS, free nytimes.com/marketing/nytvr*

STACK

Stack tests your timing. As a block tessellates across the screen, you tap at the moment it fits, building a larger ombre structure. Its beautiful palette and soundtrack make it all the more enticing. *Android and iOS, free ketchappstudio.com*

FOCUS KEEPER

Based on the Pomodoro Technique, *Focus Keeper* breaks down working into intervals of 25 minutes, with a five-minute break between. The "goal" feature will encourage the competitive to stay focused. *iOS, £1.49 limepresso.com*

WEIRD

I LOVE FUR

This app lets you stroke the scales, fur or spikes of creatures until you (or they) are satisfied. Complete a challenge to unlock other characters, such as Bipolar Bear or Fire Intolerant Dragon. Strangely therapeutic. *iOS, free geometrieva.com*

HOW DO TODAY'S TOP FUTURISTS IMAGINE TOMORROW'S WORLD?

ARCONIC AND WIRED HAVE COLLABORATED TO CREATE NONFICTION PREDICTIONS, A SERIES DESIGNED TO EXPLORE THE ENGINEERING AND MANUFACTURING INNOVATIONS THAT WILL HELP TO CREATE THE HOMES, CITIES AND TRANSPORTATION OF TOMORROW

Great minds do so much more than think alike – they think big and think far. To this end, WIRED has partnered with Arconic – a global technology, engineering and advanced manufacturing leader for major markets including aerospace and automotive – to tap into some of the world's brightest futurists and learn what's in store for humankind in 50 years' time.

The project, Nonfiction Predictions, taps into Arconic's sharpest engineering minds to highlight how materials science, advanced manufacturing and smart thinking will take us into the future.

The online series will investigate and explore exactly how our cities, homes and transportation – both across town and across the Universe – will transform and flourish.

The future may be bright, but it's also yet to be written. For a look ahead at how engineering innovations are shaping what's possible, visit the Nonfiction Predictions project at wired.com/arconic.

Images, from left: New manufacturing techniques will take us to new worlds; buildings will evolve; a change in aerospace is on the horizon.

ARCONIC'S PREDICTORS:

KLAUS KLEINFELD
Chairman and CEO of Arconic – a global leader in engineering and manufacturing.

LUKE HAYLOCK
A pioneering engineer with 16 years at Arconic, Haylock is its global aerospace technologist.

SHERRI MCCLEARY
Chief materials scientist at Arconic and inventor of innovations enabling lighter, safer vehicles.

DON LARSEN
Arconic's advanced manufacturing metallurgist and a holder of 11 US patents.

TODAY'S PROLIFIC FUTURISTS:

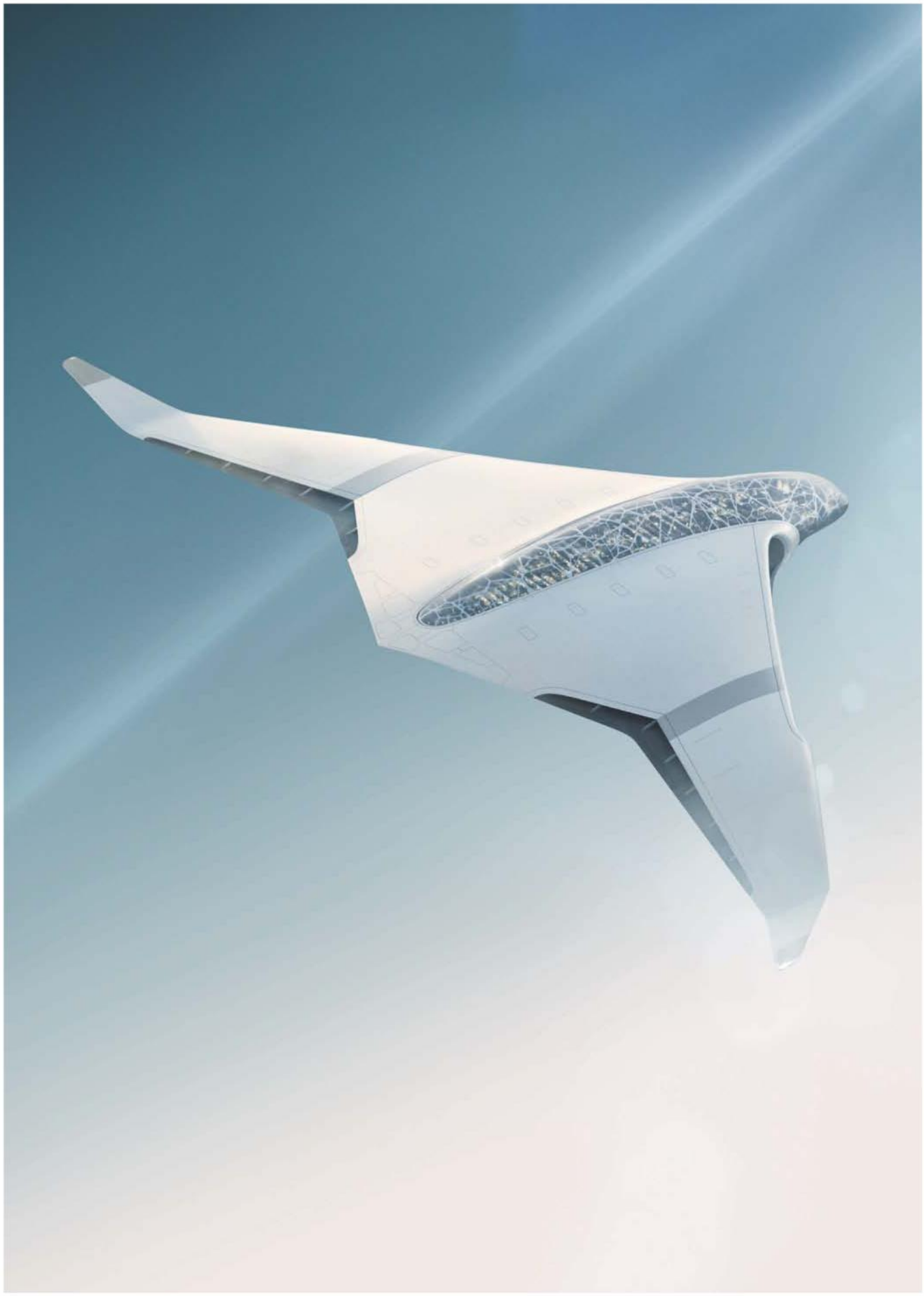
KEVIN KELLY
Co-founder of WIRED and author of *The Inevitable and What Technology Wants.*

ANNE LISE KJAER
Founder of ideas agency Kjaer Global and the Time to Think Future Trends conferences.

ADRIAN HON
Former neuroscientist, tech writer and author of *A History of the Future in 100 Objects.*

THOMAS FREY
Executive director, founder and senior futurist at think tank DaVinci Institute.

THIS ARTICLE WAS PRODUCED BY WIRED IN COLLABORATION WITH ARCONIC



A FARM DESIGNED FOR THE DESERT

Sundrop Farms is using Sun and seawater to reinvent agriculture

PART GREENHOUSE, PART SOLAR PLANT, THIS FARM IS HARVESTING food from the Australian desert. Officially launched in October 2016 at Port Augusta in South Australia after a six-year pilot, it's the first outpost of Sundrop Farms. The company wants to make farming more resilient to climate change by using the desert's plentiful sunshine, plus piped-in seawater, to grow food in arid environments. "Our farm grows more than 15,000 tonnes of tomatoes each year," says CEO Philipp Saumweber. That's 15 per cent of the Australian tomato market.

Sundrop's tomato plants are grown hydroponically, free of soil, in a watery solution fed by nutrient-rich coconut husks. "Intake water is pumped, using sustainable electricity produced by our concentrated solar plant, in a 450mm pipe over 5km to our desalination unit," Saumweber explains. The solar plant, which flanks the eight-hectare building, is made of 23,000 mirrors reflecting the Sun's heat on to a solar tower. This transforms 1,000,000 litres of seawater each day into fresh water.

Sundrop Farms produces enough truss tomatoes (*pictured right*) daily to fill eight trucks

It also drives a turbine to generate electricity. Additional water is also taken from the roof of the greenhouse.

As seawater is a natural disinfectant, the farm can operate pesticide-free. The high-saline water left over from desalination is then carried back to the sea. "Gravity is used to return water along the same course, in a larger pipe, where it is discharged into the sea only when salinity levels have returned to normal," Saumweber explains.

Sundrop's plant cost AUD$200 million (£116m) to build, including a $100 million investment from private equity firm KKR. In 2016, Sundrop expanded to Portugal and Tennessee in the US, where it's building farms to meet the needs of local supermarkets. "This means that our produce complements what is already being grown locally, rather than competing with it," says Saumweber. "Now that we have proved the commercial viability of our systems, we're aiming to bring Sundrop projects and produce to locations around the world," he says. "This is unlike any other farm on the planet."

Emma Bryce *sundropfarms.com*

Where Science Fiction Becomes Nonfiction

Outracing horses. Flying with birds. Walking on the moon. For thousands of years, these were the subjects of our wildest dreams. Now they are some of humankind's greatest achievements. We're proud that our materials and technologies have helped our partners reach distant coastlines, the skies and outer space. Bring us figments of your imagination; we'll help you put them in the history books. **Arconic. Where the future takes shape.**

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IDEAS BANK

TOM VANDERBILT

YOUR ❤️ OF A 💪 EMOJI IS OLD NEWS

In a series of lectures at the University of Cambridge in the late 1930s, the philosopher Ludwig Wittgenstein noted the trouble humans can have expressing themselves – particularly when it comes to our feelings about things or people. The use of a word such as "lovely" to describe a piece of art or music was annoyingly muzzy. And yet, he observed, "A lot of people who can't express themselves use the word frequently."

If he were a good draughtsman, Wittgenstein continued, he "could convey an innumerable number of expressions by four strokes". He sketched three simple faces: a smiley face with closed eyes; that same face with a raised eyebrow; and a smiling face with open eyes. "Such words as 'pompous' and 'stately'," he argued, "could be expressed by faces." Far from simplifying our discourse, he suggested, the crude symbols would make it more precise. "In fact, if we want to be exact, we use a gesture or a facial expression."

What Wittgenstein was proposing was a sort of proto emoji long before such things had begun to permeate our digital consciousness.

The ascent of emoji has been astonishing. In Gavin Lucas's *The Story of Emoji*, the linguist describes emoji as the fastest-growing language of all time. For instance, when emoji were added to the iOS keyboard in 2011, about ten per cent of *Instagram* posts contained emoji; that figure is now north of 50 per cent. As a study by the Georgia Institute of Technology found, emoji even seem to be crowding out their more primitive cousins, the emoticons, based on an analysis of Twitter usage.

A 2015 survey by Bangor University found that 72 per cent of participants aged between 18 to 25 felt more comfortable expressing themselves using emoji than words. But before one goes off tut-tutting about a socially blinkered, post-literate generation communicating via smiley faces, we should remember Wittgenstein's emoji.

Indeed, the problems of communication he was addressing, well before the computer age, are only magnified in electronic messaging; where, in the absence of facial gestures, intonation, pauses and other contextual cues, our language can seem sterile at best and, at worst, open to misinterpretation (if I sign off with a full-stop, and not an exclamation point, does that seem passively aggressively hostile?). Communicating online is like being in a car and trying to talk to other drivers. Without time for lengthy formalities, generally unable to see each other's faces, we use gestures – a wave, a flash of headlights, a sounded horn.

But simple language can be as hard to read as complex language. Were you honking at me? Was it a polite honk, or an angry honk? Inventors have occasionally suggested systems for cars which would display messages – like "sorry" – to other drivers, to help broaden the range of expression.

Facebook was in essence trying to solve a similar problem when, earlier last year, it unveiled "Reactions", which added "wow" and "sad" emoji, among others, to its original "like". As US magazine *n+1* noted, "like" itself was born "as an 'awesome' button, but the company decided that the language of a 'like' translated across cultural vocabularies in a way that 'awesome' didn't." Universal or not, "like" had its limits. When a friend told you of bad news, hitting 'like' – even if you were sure they would get what you meant – felt uncomfortable. "Binary 'like' and 'dislike'," as Facebook's director of product design put it, "doesn't reflect how we react to the vast array of things we encounter in our real lives."

And now that "love" has emerged as the most popular response, does a mere "like" seem tepid? And is "reacting" the same as feeling? As Dacher Keltner, part of the University of California team that advised Facebook on Reactions, put it, a tagger could in effect be saying: "I recognise that what you've done could produce this feeling, but I don't necessarily feel it."

The power of emoji is their ability to tap into the cognitive architecture for reading facial emotion (smiling and unsmiling faces are so powerful they are routinely used in psychology as unseen "primes" to influence people's response to other things). At least since Charles Darwin, who showed 20 house guests a series of photographs of people and asked them to judge what emotion was being displayed, the legibility and near-universality of facial expression has been known. Darwin thought we had facial expression before language because it was key to our survival – one needed to signal danger, disgust, maybe even joy, before we invented words to go alongside. It was social media 1.0. In this sense, emoji are not a new language, but the oldest one of all.

Tom Vanderbilt is an American journalist and author of *You May Also Like: Taste in an Age of Endless Choice* (Simon & Schuster UK)

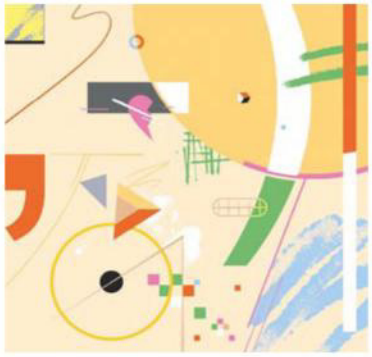

ILLUSTRATION: EDWARD TUCKWELL

DAVID KRAKAUER

SINGULARITY COMES FROM CLAY, NOT COMPUTERS

Four thousand years BCE in the ancient Near East, a region we have come to describe as the cradle of civilisation, Sumerian scribes made replicas of their minds in mud and created the clay tablet – the world's first silicate chip.

Five thousand years later, silicon semiconductors, ferromagnetic films and floating gate transistors have amplified the recording power of clay a quintillion times. Trends in processing and storage technology suggest to futurists that before too long, human thought, as the Babylonian mythology *Enûma Eliš* described so presciently, "shall be bound" and "to a unity brought together".

The technological singularity – that moment when humanity is surpassed by intelligent machines and absorbed by them – was first described by the mathematician Stanislaw Ulam, as a defining moment when "the ever accelerating progress of technology" leads to a point "beyond which human affairs, as we know them, could not continue". For the engineer Ray Kurzweil, this event marks overcoming the limitations of biological brains.

There is a tendency to view one's own time as uniquely sophisticated, to conceive of the past as primitive. Yet with clay tablets, humans overcame the limitations of their brains 5,000 years ago. The first singularity took place in the Stone Age.

It is only recently that we have grasped what it means for individual brains to extend into the world of culture, fuse with the thoughts of society through the properties of physical artefacts and technologies, and then reabsorb the experience of the collective by accessing these technologies.

And what we have learnt is that the evolution of human intelligence is a continuous process of alternating outsourcing and reintegration, an endless series of fusions and fissions among individuals and collectives. To make this organic-inorganic narrative clear, let's consider numbers.

In the western world we have grown complacent about our Indian-Arabic number system. These numbers possess both a zero and a place-based value. One might assume that previous number systems were less able and that our decimal numerals are a late and highly evolved means of representing magnitude and relation. This is far from the case. The two earliest number systems were Egyptian and Sumerian. The ancient Egyptian numbers were also base ten, and each power of ten was represented by a different hieroglyph – from strokes (one), to cattle (ten), ropes (100), and lotus flowers (1,000). The Sumerians used base 60, written in cuneiform characters, one for units and one for powers of ten. A legacy of the sexagesimal base persists in our units of time – 60 seconds to the minute and 60 minutes to the hour. Cultures are swimming in unfamiliar number systems: base 27 among the Oksapmin people of New Guinea; base 20 among the Yoruba of West Africa; and base 12 among the Nimbi of Nigeria.

David Krakauer is president of the Santa Fe Institute and the William H Miller professor of complex systems

In all of these culturally evolved instances, numbers were inscribed upon suitable physical materials in order to encode matters of great value and where the constraints of time and space would necessitate outsourcing of arithmetical and mathematical ideas.

Numbers have evolved as a means of achieving long-lasting consensus. By being placed in the "public domain" these numbers have achieved incredible exponential returns through the collective deliberation of generations. Whereas thoughts restricted to individual brains depend entirely upon the knowledge and ability of one brain, ideas in the world can be manipulated across time and space by countless minds, and achieve through collective consideration a significant non-linear increase in stored knowledge.

It is therefore the combined memory (stored solutions that span generations) and computational (worked on by many individuals) representational powers of the silicate chip, and its many subsequent Stone-Age cousins, that make their realisation in history as candidate singularities.

It is true there is something about our contemporary solid-state artefacts that suggests a form of independence or autonomy from humans which merits special consideration. Whereas silicate chips need to be modified by hand, silicon chips can be modified by current. And although silicate chips can be transmitted across vast distances, they do so slowly, unlike calculations in silicon that travel at near light speed. On the other hand, silicate chips have successfully stored information for more than 5,000 years, whereas digital media is considered resilient if it can store information for more than a decade.

The evolution of human intelligence has always been about overcoming the constraints of soft organic matter. The adaptability of cells and tissues, their ability to perpetuate through replication, comes at a cost of fragility, limited scale and the needs of the generalist. Specialist tasks can be better served by more restrictive materials. And collective performance can be facilitated by platforms that support the combined activity of populations. Our earliest cognitive platform was the silicate chip of the Sumerians – clay tablets upon which humanity achieved its primal, introductory singularity.

ILLUSTRATION: JON FOX; ANDRÉ BERGAMIN

LUKE DORMEHL

ONLY ONE WEAPON CAN TAME THE AI OVERHYPE

Thanks to neural networks – digital approximations of the way that the human brain learns – artificial intelligence has made enormous breakthroughs in everything from creating machines that can recognise faces with more accuracy than a human, to building cars capable of driving themselves, to recently, a computer "Turing test for sound" which can watch silent videos and predict the sounds that should accompany them.

But it very nearly didn't happen like this. Forty years ago, research into neural networks almost stopped altogether. Budgets were slashed, plugs were pulled and students were advised by their teachers that researching neural networks was a bit like dating the loser in school: they'd never amount to anything and you'd just get hurt in the process. Certainly there were things neural networks weren't capable of at the time, but it's equally true that a large amount of the backlash the field suffered came down to the massive amount of hype it had received. Researchers, particularly in the rival, more established field of symbolic AI, were perturbed by articles like the one *Science* magazine published in 1958 about neural nets, entitled "Human Brains Replaced?" Reading it today, the crazy thing is how accurate the article was: predicting machine learning capable of making decisions and translating languages. But neural networks weren't capable of doing all of that just then, and the vitriolic response to those stories helped crush the hopes of people interested in the field. It was only the willingness of a group of strong-willed researchers in the 80s, willing to work away in relative obscurity for years, that pulled neural networks back from the brink. Today, many of them are the top experts in the field and enjoy high-level jobs at companies such as Google.

Luke Dormehl is a journalist and the author of *Thinking Machines: The Inside Story of Artificial Intelligence and Our Race to Build the Future* (WH Allen)

Neural networks, of course, aren't the only technology to prompt overhype and, inevitably, disappointment. Robotics has had a similarly challenging time. In the 60s, a ground breaking robot called Shakey set benchmarks in fields such as pattern recognition, information representation, problem solving and natural language processing. It has, quite rightly, been described as the world's first general-purpose robot capable of reasoning about its own actions. But when it was profiled in *Life* magazine in 1970, Shakey was called the world's "first electronic person" and was said to be (wrongly) capable of travelling "about the Moon for months at a time without a single beep of direction from the Earth".

So are journalists to blame? Possibly, but not exclusively. Overhype, like success, has many fathers. Researchers, for instance, have benefitted from hype when it comes to funding. At an AI conference in Boston during the 70s, one researcher told the press that it would take just five more years until all of us had smart robots in our homes picking up stray socks. He was confronted by a furious colleague who said, "Don't make those predictions! You're underestimating how long this will take." Without pausing, the researcher responded, "I don't care. Notice all the dates I've chosen were after my retirement date."

As AI became big business in the 80s – initially thanks to the boom in what are called "expert systems" – we began to encounter a new species: venture capitalists. Although many VCs believe in the transformative abilities of technology, it would be naïve to think that big business doesn't bring with it a certain "pump and dump" mentality, whereby promises are inflated until the metaphorical balloon finally pops under the pressure. Neural networks recovered from this effect, but there are plenty of other examples of technology in which their macro story was correct, but their inability to match the hype in the short term proved to be a blow too fatal to overcome.

AI may be more subject to hype than any other field. It is a discipline which exists perpetually on the brink of science fiction, being sometimes described as "cool things that computers aren't yet capable of". AI is the only subject I've come across where successes are shuffled out of the field altogether: no longer considered "AI proper", but rather some lesser sub-field of it. It's a bit like a magician dismissing illusions as simple tricks the moment he discovers that there's no real magic in it, but rather a trapdoor on the stage.

There are plenty of short-term benefits to hype but, ultimately, it can bring with it more problems than it solves. However, with an army of excitable journalists, eager VCs and perpetually optimistic computer scientists, it's not the kind of thing which can easily be lifted out of the field like a dodgy line of code. We need a more thoughtful approach to the subject of building thinking machines – meaning less sensationalism, more stability and, ultimately, satisfying progress.

Of course, the other risk of hype is that in our eagerness to look to the future and to all that machines are not yet capable of, we overlook the massive strides that have already been made.

LAURIE WINKLESS

MOLECULAR ECOLOGY CAN SHORTEN YOUR UBER RIDE

We've all been there. Stuck in a city-centre traffic jam, a sea of red brake lights ahead. Grumpy and stressed, you edge forward, silently (or occasionally, loudly) cursing the other drivers on the road. When asked, somewhere between 80 and 90 per cent of drivers believe that their skills behind the wheel are above average. Clearly, lots of drivers are wrong. But the idea that traffic jams must be the fault of someone else is a pervasive one, and it's reflected in the language we use to discuss them. We say things such as, "Oh, the traffic was terrible," or, "The roads were so busy this morning" – as if the jam is a separate entity to the drivers caught up in it.

The science behind how and why traffic jams form tells a very different story. And it is one that's being collectively written by researchers from a diverse range of fields. From molecular ecology and human behaviour to network science and urban planning, there are thousands of people trying to understand traffic and find new ways to keep it moving.

Road congestion can be caused by any number of factors – bad weather, an accident, roadworks or just by too many vehicles competing for too little space. But there's also the "jamiton" or "phantom traffic jam", where, for no discernible reason, traffic builds up and then eases. A now-famous video of how these types of jams form shows 22 cars being driven on a closed track. The driver of each car was instructed to get up to 30kph and maintain that speed at a safe distance from the car in front. But the system broke down very quickly, with some cars left at a standstill while others were accelerating. The reason is simple – people have trouble maintaining a constant speed. Say one driver finds themselves driving just slightly above the speed limit – to correct for it, they then tap on the brakes. The car behind then overcompensates for this sudden braking, as does the car behind that one. This causes a start-stop shockwave that travels backwards through traffic.

We usually associate the concept of collective behaviour with the natural world more than the urban jungle. A paper published by German scientists in 2015 looked specifically at traffic flow in ant colonies. Black-backed meadow ants construct and maintain permanent roadways not unlike our own – a fixed width and a smooth surface, clear of obstacles. By observing ants using the route, Christiane Hönicke and her colleagues could investigate the ant etiquette involved in the rapid flow of traffic in and out of the colony. Surprisingly, they found that, as the trail got more crowded, the ants sped up. In fact, they increased their speed by about 25 per cent as the density doubled.

At these higher speeds, collisions were more frequent between ants – possibly not a situation that human drivers should be emulating. But another factor in ant traffic flow was the evolution of "lanes" as the route got busier – something that has been observed by mathematical modellers in India too. Most researchers also agree that individual ants tend give each other a lot of headway. This gives them more time to react to any incidents, reducing the risk of kick-starting a jamiton. Ants could teach us a thing or two, but changing driver behaviour on the roads can be a challenge. For example, dynamic late merge, also known as the "zipper system" has been shown to greatly reduce congestion when merging two lanes into one. But despite this, many drivers still opt for the more polite (and less efficient) early-merge option.

Marta C González of MIT's Civil and Environmental Engineering Group believes that we could all benefit from taking a less selfish approach to driving. Using smartphone data, she showed that taking just one per cent of cars off the roads from specific neighbourhoods in Boston and San Francisco could reduce travel time for all other drivers in those cities by up to 18 per cent. In early 2016, González found that in cities including Rio de Janeiro and Lisbon, even if a small number of drivers took a slightly longer route, the total time lost to congestion could drop by 30 per cent.

Infrastructure has a role to play too, including traffic lights within cities. They use sensors embedded in the road to continuously feed information on traffic flow back to a central control centre. But cities such as London are making lights smarter. There, thermal cameras monitor the number of pedestrians and cyclists at certain road junctions and adjust the "green-light time" to give them an official head start. In August, Audi announced that their new Q7 and A4 cars will be able to communicate with smart traffic lights, providing a green light countdown for drivers.

Longer term, the biggest challenge facing traffic managers will be the mix of transportation on the road – namely, a growing number of autonomous vehicles, surrounded by many human-controlled ones. A full move to driverless cars would have a major impact on road infrastructure too. Because they can continuously communicate with each other, driverless cars could potentially speed safely through junctions, removing the need for physical traffic lights. Where will that leave pedestrians? Well, that's a question that designers don't yet have an answer to.

Laurie Winkless is a New Zealand-based writer, physicist and science communication consultant

ILLUSTRATION: GIOVANNA GIULIANO

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The Art of Window Styling

Above: TUMI's Regent Street store was the venue for the awards ceremony

READY, JET SET, GO

IN NOVEMBER 2016, WIRED AND LUXURY TRAVEL BRAND TUMI HELD THE SECOND INNOVATION IN TRAVEL AWARDS TO CELEBRATE THE COMPANIES AND DESTINATIONS DELIVERING THE SECTOR'S FINEST EXPERIENCES

AT THE AWARDS PARTY:

FIRST CLASS
The evening kicked off the 2016 party season, with TUMI's flagship London store hosting all nominees from the awards.

YOUR CAPTAIN SPEAKING
Victor Sanz, TUMI's New York-based creative director, flew to London to kick off the Innovation in Travel Awards.

ALL INCLUSIVE
A range of cocktails were mixed on site by TUMI mixologists – keeping the networking and celebrations going until late.

A VIP BOOKING
Guests flew from Europe and beyond for the awards – representatives from Japan even made the 9,000km trip.

SPECIAL ANNOUNCEMENT
Jeremy White, WIRED's product editor, announced the award winners for the second year running.

LONDON'S LANDSCAPE
When the ceremony finally came to an end, many guests dispersed to find an after-party in the chilly London night.

"The key focus for us is perfecting the journey – pushing the limits of innovation and elevating our brand," said Victor Sanz, creative director of TUMI, as he introduced the TUMI X WIRED Innovation in Travel Awards in London last November. "All of the nominees here are leaders in the global travel market and are pushing the boundaries of their industry and the customers' experience."

Voted for by wired.co.uk readers throughout autumn 2016, the winners were announced on stage by Jeremy White, WIRED's product editor.

Hilton McLean Tysons Corner picked up the Best-connected hotel/resort prize for its experimental hotel concepts, and Best in-flight experience went to Virgin America for its power outlets, Wi-Fi and Netflix, Spotify and *The New York Times* for all passengers.

Travel app *Pana*, which blends human knowledge with machine search, won Best specialist travel agent/concierge; Best UK-based travel influencer went to travel blog *A Hotel Life* for its refreshing taste of exotic locations; Canopy by Hilton Reykjavik City Centre secured Iceland the Best travel destination or experience; and Spain's Logroño high-speed train station picked up Best transport hub for its futuristic design.

For more about Tumi, visit tumi.com

PHOTOGRAPHY: SUN LEE

GEAR

MICROSOFT SURFACE STUDIO

The second in the Surface range's series of strikingly designed hinges has a desklamp-style support that's perfectly balanced for graceful motion between drafting at an angle and traditional monitor mode. An ultra-thin 28-inch display contains 13.5 million pixels of rich colour. There's also tactile interaction through ten-point multitouch, a Bluetooth Surface Pen and a clever puck-shaped Surface Dial controller. *£2,649 microsoft.com*

- Designers can switch between colour modes at the push of a button
- Press and hold the Surface Dial to display a menu of tools and apps

FETISH

WORDS: KATHRYN NAVE. PHOTOGRAPHY: MITCH PAYNE

INVENTABLES CARVEY
Fully enclosed for safety and mess-minimisation, Inventables' 3D carving machine is as at home in the hands of children as it is sat on a designer's desktop. It cuts plastics, soft metals, foam, wax and more. The machine's software auto-adjusts its settings to match the material. Your designs can be created in *Easel*, an easy-to-use web app. *$2,500 inventables.com*

CRAFT DESIGN TECHNOLOGY SCISSORS
The Samurai-sword inspiration for these scissors is carried through from design into manufacture, with each pair being created in the Gifu prefecture of Japan, an area once famed for its sword-making artistry. A universal configuration means these clippers are compatible with both righties and lefties. *£60 the journalshop.com*

SHARPEST TOOLS IN THE BOX

From whiskers to woodwork and Wagyu, WIRED selects six angular implements that are good enough to make the cut

RZR
Why let springs, hinges and flex-balls do what your wrist was designed for? The RZR razor uses just three components: a simple, solid titanium handle; a premium-quality blade; and a head designed to maximise contact between blade and skin. *€89 rzrshaving.com*

CUTTING

IAIN SINCLAIR CARDSHARP4
CNC machined from a thin strip of aluminium, this pocket knife has a 65mm 420 surgical stainless-steel blade. It weighs just 24 grams and can be folded down to a 2.2mm-thick credit-card-sized profile. *£55 iainsinclair.com*

DEL BEN PRIMITIVE KNIFE
Italian designer Michele Daneluzzo found inspiration in the simple efficiency of Stone Age tools. His steel Primitive Knife resembles a flake of flint and incorporates a contoured top-ridge as a secure hand-grip. Perfect for Paleo fans. *AU$329 harveynorman.com.au*

WORDS: KATHRYN NAVE. PHOTOGRAPHY: MITCH PAYNE; ROGER STILLMAN

FESTOOL SWORD SAW
Weighing just 6.5kg, the Sword Saw has a chainsaw blade that can slice timber and hard insulation materials up to 200mm deep. Its drawing cut enables jolt-free operation, while a swivelling range of 0-60° allows for deep mitre and compound angles. Guide-rail compatibility means clean cuts every time. *£714.14*
axminster.co.uk

SAMSUNG FAMILY HUB MULTI-DOOR FRIDGE FREEZER

You may be able to remember how many eggs you have left in the fridge, but are you sure they'll last until next week? Three Wi-Fi-connected cameras built into the 550-litre Family Hub and a companion app let you not only check your supplies, but also digitally track your food's expiry dates for updates on when to restock.

From £4,500
samsung.com

FETISH

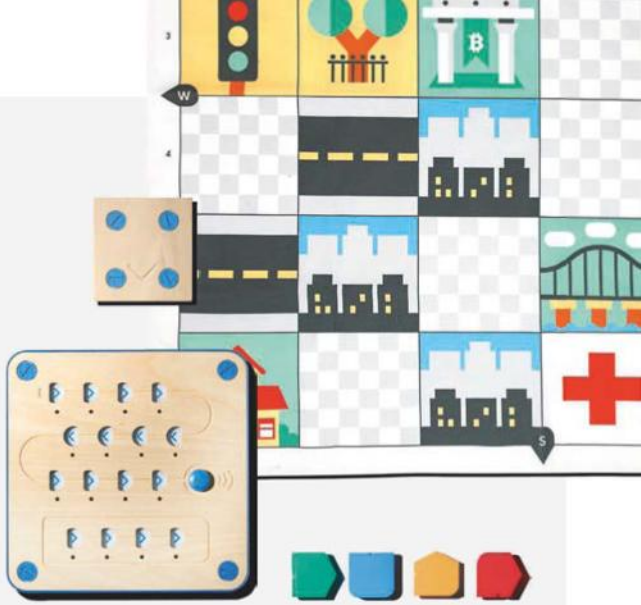
- An integrated 21.5-inch tablet can display a calendar, messages and recipe ideas
- Use the appliance's entertainment system to listen to music or watch TV shows

WORDS: KATHRYN NAVE. PHOTOGRAPHY: MITCH PAYNE


CODING

GET KIDS TO CRACK THE CODE

WIRED finds out if these games can inspire a generation of programmers



TEST

HOW WE TESTED

To test these coding toys for children, WIRED enlisted the help of a crack team of five mini-testers aged between four and eight – supervised by a grown-up, of course. We rated how easy it was for each game to get started, how well they engaged the children and how long each of the games kept them occupied, as well as whether they wanted to play them again.

OSMO CODING

Osmo's coding kit (*left*) uses the same concept as Cubetto, but the difference here is that the intrepid Awbie inhabits a virtual iPad app world. The iOS-only game, aimed at five- to 12-year-olds, uses coloured plastic blocks that snap together to create instructions for Awbie. He gambols his way between trees and over rivers while stuffing his face with pies (a favourite detail for Lake, WIRED's five-year-old tester). With no separate command console, there is a neat method of transferring information from the instruction blocks to your screen. A stand holds the iPad while a mirror attachment points the camera to the surface in front of the screen where you assemble the blocks. WIRED's tester found it easy to get to grips with the blocks, and it felt like a small step to an on-screen "blocky" programming language. Parents, however, may wonder why it is necessary to buy the starter kit as well. **8/10** *£49 (starter kit £75) playosmo.com*

CUBETTO

This beautiful – if expensive – toy makes the bold claim that it can introduce coding to children as young as three. And, through a simple but charmingly sedate robot, it does just that – without going anywhere near a computer keyboard. The eponymous cube-shaped droid comes with a separate control console and 16 commands in the form of colourful wood blocks. To give the two-wheeled machine instructions, simply add the blocks in order (just like lines of code), press Go and off it trundles. Getting started is easy with a step-by-step manual. The pack also contains a metre-square cloth map for your robot to navigate. The narrative for map one is Cubetto's first day at school, but there are four other engaging story maps in the Adventure pack: the city, Ancient Egypt, deep sea and outer space. The kit is robust, but what's clever here is that it gives children a fun route into the concepts and jargon of computer coding using tangible real-world objects. It may get repetitive over time, however. **7/10** *£159 (Adventure pack £50) primotoys.com*

CURIOUS KIT

Construct a remote-controlled car, a traffic light, a stirrer, a pinball machine... the list goes on. This versatile pack includes two DC motors, a tilt switch, a button switch, a slider and an RGB LED. Aimed at seven-year-olds and upwards, these "SAMs" can be hooked up via Bluetooth to a computer or tablet. To unlock their full potential you'll need the *SAM Space* app. The physical SAMs appear in your virtual tool box and can be combined with virtual SAMs. Some of these virtual SAMs are easy enough to figure out, but WIRED had no idea how many of them worked. The instructions weren't much help, either. This is a brilliant idea that WIRED wanted to love, but we were left scratching our heads. **4/10** *£149 samlabs.com*

WORDS: JAMES RANDERSON. PHOTOGRAPHY: MITCH PAYNE; ROGER STILLMAN

ROXY RUSSELL MEDUSAE COLLECTION
The diaphanous glow and delicate tentacles of these jellyfish-inspired lamps will fill your room with the calm of the sea. Made from velum-finish polyester mylar, the Medusae collection is available in four varieties, including the Polyp pendant lamp (*centre*).
From $375
roxyrussell.bigcartel.com

RE-SEA ME STOOL

This stool flips the dynamic from discarding waste into the ocean to extracting sustainable materials from it. Dutch designer Nienke Hoogvliet collected discarded fish skins, then tanned them into a beautiful, strong leather. The manual technique uses no harmful chemicals and Hoogvliet is now working on scaling it up to larger projects. *£poa nienkehoogvliet.nl*

INODA+SVEJE MANTA RAY CHAIR

The Manta Ray chair combines elements of the classic Windsor chair design with influences from ocean rays' tapering bodies. Danish-Japanese design partnership Kyoko Inoda and Nils Sveje have created a harmonious balance of organic softness and formal rigour. A thick rear support contrasts with its delicate spindles and a seating surface pared down to the thinnest degree. *€1,600 shop.inodasveje.com*

CREST OF A NEW WAVE

WIRED explores ocean-inspired treasures

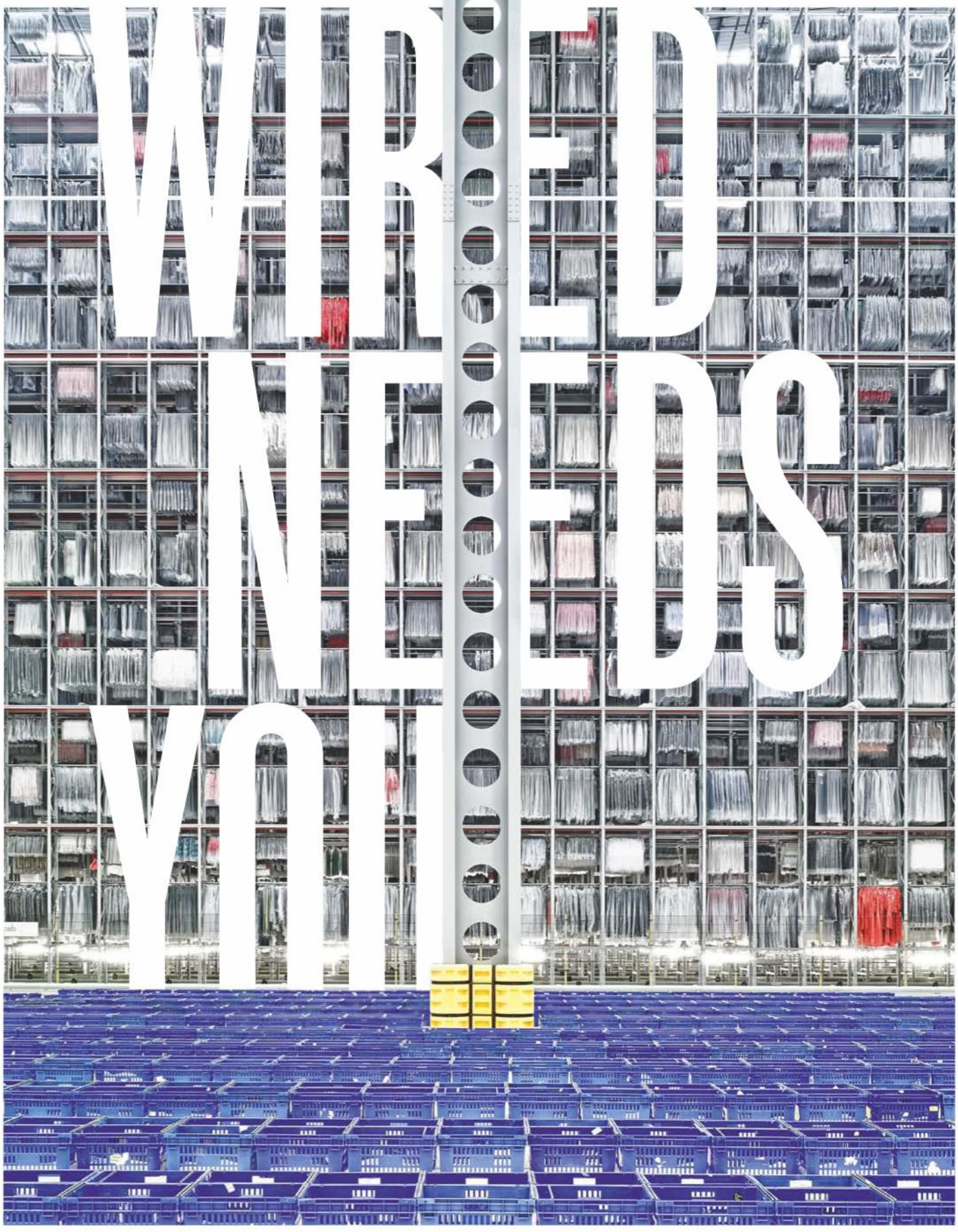
OMEGA SEAMASTER PLANET OCEAN DEEP BLACK

The new 45.5mm Deep Black has a GMT function powered by the new Master Chronometer calibre 8906. Built from a single block of ceramic, it is the first of its kind to be rated down to 600 metres and resistant to 15,000 gauss. There are four models: black, red, blue and this piece with Sedna gold accents on a leather strap and matching gold hands and indices. *From £7,900 omegawatches.com*

TINNIE 10 BOAT

Resembling the aggressive angles of a destroyer's prow when viewed in side profile, this perfect isosceles triangle of a boat leaves space for two side-by-side passengers at the wide rear. Thick but lightweight aluminium construction means the boat is just 79kg, making for a snappy ride on its 10hp four-stroke engine. *£tbc jruiter.com*

WORDS: KATHRYN NAVE; JEREMY WHITE. PHOTOGRAPHY: MITCH PAYNE



WIRED

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WORDS: KATHRYN NAVE. PHOTOGRAPHY: MITCH PAYNE

SONY MDR-Z1R STEREO HEADPHONES

These cans are engineered to deliver an impressively wide frequency range. A newly developed diaphragm incorporates a magnesium dome and liquid crystal polymer edge for up to 120kHz playback. Their special acoustic filter eliminates any unintended reverberations to ensure only the purest form of sound reaches your eardrums. *£1,700 sony.co.uk*

SONY TA-ZH1 ES HEADPHONE AMP

With feedback-eliminating S-Master technology, Sony's Signature-series amplifier delivers a pleasingly precise audio experience. For extra sonic warmth, the DC Phase Linearizer allows you to adjust amp voicing. This helps to deliver a traditional analogue sound while correcting errors caused by digital switching. *£1,640 sony.co.uk*

SONY NW-WM1Z WALKMAN

The NW-WM1Z matches the highest auditory quality with premium looks. Its gold-plated, oxygen-free copper chassis not only catches the eye – its conductivity also lends a natural acoustic sound. Integrated DSEE HX upscaling technology analyses your music and replaces lost data to produce near-high-res audio. *£2,562 sony.co.uk*

DURUM ROLL, PLEASE...

WIRED tries its hand at creating authentic carb-fuelled dishes with five pasta makers

WORDS: EMILY PECK. PHOTOGRAPHY: ROGER STILLMAN; MITCH PAYNE

KITCHENAID 4.8L STAND MIXER WITH SHORT PASTA MAKER ATTACHMENT

For those who already own a stand mixer, this steel and plastic attachment will come in useful. The dough is prepared in a metal bowl and then the plastic spinner is filled to extrude pasta from the plastic cutters. In our test, the middle part of the pasta sheet came out evenly, if not a little thick, but both edges were ripped. "The pasta comes out slowly and I don't feel the cutter is safe as it doesn't have any protection," says Simone Remoli. "This model is good for short-shape pastas such as fusilli and rigatoni." **6/10**

£499 for stand mixer; £199 for pasta attachment
kitchenaid.co.uk

Time to prepare:
Dough 2 minutes 30 seconds
Sheet of pasta 17 seconds
Tagliatelle 25 seconds

LAKELAND PASTA MAKER MACHINE

Designed for tagliatelle, fettuccine and sheets, this machine made smooth pasta. Remoli found that the pasta-sheet rollers were not straight, so the results were not as even as he would have liked. As it is easy to clean and flexible enough to make a variety of pastas, this is a good budget option. **7/10** *£22*
lakeland.co.uk

Time to prepare:
Dough 18 minutes by hand
Sheet of pasta 4 minutes 10 seconds
Tagliatelle 5 minutes 50 seconds

PASTA MAKERS

SMART WORLDWIDE MODERN PASTA MAKER

Quiet in operation and with all the features to create perfect pasta, this machine impressed Remoli. He particularly liked the dryer, which makes sure the pasta doesn't stick. **8/10** *£136*
wayfair.co.uk

Time to prepare:
Dough 4 minutes 30 seconds
Sheet of pasta 12 seconds
Tagliatelle 22 seconds

PROCOOK PASTA MAKER

Pasta dough has to be prepared by hand before using this machine. In our test, Remoli noted "smooth and even" results. He also liked the eight thickness settings and that the machine created uniform shapes. "This design is ideal for ravioli," he concludes. **6/10**

£32 procook.co.uk

Time to prepare:
Dough 18 minutes by hand
Sheet of pasta 3 minutes
Tagliatelle 3 minutes 30 seconds

HOW WE TESTED

WIRED asked chef Simone Remoli, owner of London restaurant Pasta Remoli (pastaremoli.co.uk) – specialists in traditional handmade pasta – to test five of the latest pasta makers. Remoli assessed each model on performance, durability, ease of cleaning and versatility and told us what type of pasta he thought would work best in each model. We timed how long it took Remoli to make a sheet of 50cm egg pasta and a batch of tagliatelle in each machine. He gave each design a WIRED score out of ten.

Digital extra!
Download the WIRED app for Simone Remoli's oxtail ravioli recipe

PHILIPS HR2355/07 PASTA AND NOODLE MAKER

Remoli found this model to be a very intuitive design, with a timer and electronic setting, that was simple to use and easy to clean. "The machine can create the dough, and then extrude the pasta from the different cutters," he says, "so it's straightforward." The dough did come out a little crumbly, however. The process, from making the dough to cleaning the machine, took just 20 minutes. "Its best use is for spaghetti and tagliatelle," says Remoli.

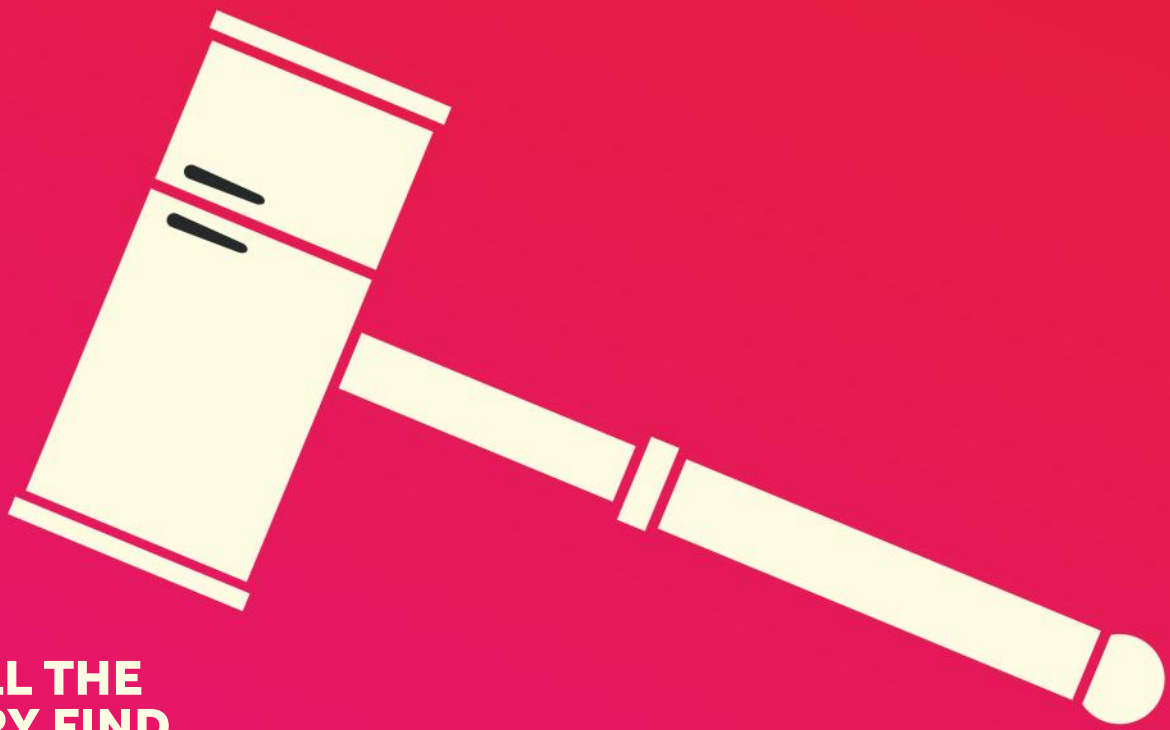
7/10 *£169*
coolshop.co.uk

Time to prepare:
Dough
3 minutes
Sheet of pasta
90 seconds
Tagliatelle
90 seconds

WIRED shot this month's products at Soho Works Shoreditch, (*sohoworks.com*), a workspace for creative businesses to hire in London

TEST

XL CATLIN



WILL THE JURY FIND YOUR FRIDGE GUILTY?

Who'd have thought that everyday accessories could be hacked and used in cybercrimes? When technology becomes connected faster than our ability to keep it safe, we need to ask the right questions to stay ahead.

For more Forward Thinking, visit **xlcatlin.com**

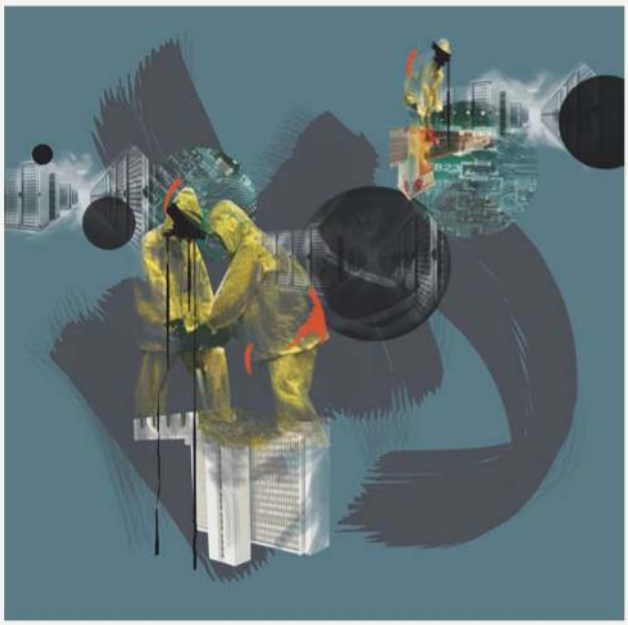
MAKE YOUR WORLD GO >>>

EVENT

WIRED SECURITY

The first WIRED Security summit, held at Canary Wharf in London on October 20, tackled key challenges in the sector – from data policy and business breaches to bug hunts and cyber warfare. Turn the page for our event debrief.

BY **Stephen Armstrong.** ILLUSTRATION: Lizzie Gill



MAKE A HACKER YOUR BEST FRIEND

Based on presentations by **Jamie Woodruff**, *technical director, Metrix Cloud;* **Mustafa Al-Bassam**, *security adviser, Secure Trading;* **Alex Rice**, *co-founder and CTO, HackerOne*

To stay safe, open your doors to hackers and share information about security issues. This was the message from the Learning from Hackers session.

White-hat hacker Jamie Woodruff, ex-LulzSec co-founder Mustafa Al-Bassam and HackerOne founder Alex Rice all agreed that transparency is key to safety. The companies posting the biggest bug bounties for hackers are making the safest software, argued Rice – urging the room to "engage hackers in a productive way... encourage them to use their creativity for good, rather than leaving them on the outside."

HackerOne encourages anyone to find bugs in a company's software and pays a bounty for any vulnerabilities identified. Rice has hackers working with Twitter, on full software takeovers, and on internet-of-things devices, from vacuum cleaners to connected cars.

"Android, iOS and Chrome are posting huge bounties and asking hackers to prove they can carry out a full takeover," Rice explained. "They have realised that the earlier you have hackers engaged, the better off you will be."

Al-Bassam proved Rice's point. As part of the group that hacked Sony, Fox and the FBI, he received a suspended sentence and was banned from the internet for two years. He's now security adviser for Secure Trading: "We hack companies with big security teams by using simple vulnerabilities," he said. It's because companies don't talk to each other about security that problems arise.

"Yahoo! was hacked in 2014, but kept it from the public because it would affect their ability to compete with other tech giants," he argued. "Amazon sells tonnes of internet-of-things devices, but most of them are insecure. If companies become more transparent, customers can make more informed decisions on what products to use and companies can know which customers to trust."

Open dialogue, all three agreed, makes everyone safer.

"I no longer have to hack 50 companies. I can hack one cloud and I get every employee using that cloud."
– Sadie Creese, professor of cybersecurity, University of Oxford

MEET THE SPEAKER #1:
Sadie Creese, *professor of cybersecurity, Department of Computer Science, University of Oxford*

What is the easiest, most effective way of hacking any environment? Sadie Creese, professor of cybersecurity at the University of Oxford, had the answer: be on the inside. "And be there for a long time to gather the knowledge to go for the highest-value stuff."

Creese has been working in computer security since 2000. "Over those years we've invested intellectual resources, time and infrastructure to make sure it's hard to break into the systems," she explained. Despite this, "the insider threat is massive."

Insiders could be disgruntled employees, people under stress or those with vulnerable devices – "We're already cyborgs to an extent," she argued. "You couldn't take away our mobile phones if you tried, and some of us will have devices implanted under our skin for health reasons."

Recent cyberattacks on celebrities illustrated another weakness for organisations. "I no longer have to hack 50 companies, I can hack one cloud and I get every employee using that cloud," she explained.

The solution? Become a mindful employer. "We're not dealing with people and technology in tandem – both are equally important," she said. "You must learn what your people do on a normal day so you can spot anomalies. And you need to be aware of pressures on staff that may make them more open to coercion."

KEEP TABS ON UNUSUAL BEHAVIOUR PATTERNS

Based on presentations by **Sadie Creese**, *professor of cybersecurity, Department of Computer Science, University of Oxford;* **Staffan Truvé**, *CTO, Recorded Future;* **Dave Palmer**, *director of technology, Darktrace;* **Cameron Colquhoun**, *managing director, Neon Century*

In the future, artificial intelligence, predictive intelligence and even monitoring open-source intelligence will be crucial in preventing cyberattacks.

Staffan Truvé, CTO of predictive-software firm Recorded Future, suggested that clues for impending hacks were dropped all the time on GitHub and the dark web. "We spend a lot of money trying to fix things *after* they happen, but we should stop the attacks *before* they happen," he suggested.

By building mazes and walls, we're giving intruders a challenge, he argued. Learning the ways hackers work and using predictive intelligence "to figure out who wants to attack us, what motivates them, where are they attacking and where the weak spots in our systems are" will help prevent assaults.

And the threats are increasingly personal, warned Darktrace's director of technology Dave Palmer. "The widespread age of machine learning and automation is imminent," he explained. Cybercriminals will launch ransomware attacks on smart TVs, self-driving cars and even MRI scanners, or alter the geophysical datasets that oil companies use to decide where to drill next.

AI can help, he said. Smart data warehouses could make decisions about how users are interacting with them, or weed out spam emails. "We can't imagine future attacks," Palmer warned. But machine learning can understand how businesses might typically operate, and search for unusual behaviour that could signal an impeding attack.

For Neon Century managing director Cameron Colquhoun, open data is becoming a source for criminals looking to plant false information and benefit from short-selling company stock. German payments company Wirecard's share price fell, he explained, after a research institute called The Tower published a report falsely accusing the company of money laundering and corruption.

"It looked like an open-source intelligence report – lots of screen shots, LinkedIn network diagrams and so on, proving this business was not worth investing in," he explained. The answer? "Proactively manage your online footprint – make sure you know everything that's out there."

"We spend a lot of money trying to fix things *after* they happen, but we should stop the attacks *before* they happen."
– Staffan Truvé, CTO, Recorded Future

CYBERATTACKERS ARE THE NEW MAFIA

Based on presentations by **Moty Cristal**, *founder & CEO, NEST Negotiation Strategies;* **Mikko Hyppönen**, *security expert;* **Troy Hunt**, *founder, Have I Been Pwned?*

Cybercrime is changing – and understanding cybercriminals is increasingly complicated, negotiator Moty Cristal, security expert Mikko Hyppönen and Have I Been Pwned? founder Troy Hunt warned.

"In the early days of malware they were being written for fun and the attackers had no motives," Hyppönen said. The Finn is the chief research officer for F-Secure and has been battling cybercrime since 1991. "Today there's activists and governments – but the most common is organised online crime syndicates, the new Mafia."

Hyppönen receives 350,000 to 450,000 malware samples per day from around the world and estimates that 95 per cent of those come from organised criminals. "Of course, getting targeted by a foreign intelligence agency is really bad," he admitted. "But most organisations have nothing that would be interesting to foreign spies."

Cybercriminals' sites have Mafia-like themes, and cybercrime is big money. Moldovan hackers Evil Corp, for example, stole millions of dollars in hits on 300 banks across 2015.

For ordinary citizens, Hunt suggested, teenage hackers are still an issue. "Very often it is a scared kid who approaches me," the 39-year-old security specialist told the room. "I try not to ask too many questions when people send me the data – I'm just interested in whether it is legitimate and where it came from."

Hunt himself deploys security such as two-factor authentication, but has still been breached. "As a consumer, there's not much more we can do about that other than being conscientious about what we put online," he explained.

MEET THE SPEAKER #2:
Jamie Woodruff,
technical director, Metrix Cloud

You might think of hackers as kids sitting in darkened rooms, white-hat hacker Jamie Woodruff told the conference, but they could just as easily be your doctor.

In the Learning from Hackers session, Woodruff – who works as a certified penetration testing engineer for UK-based Metrix Cloud – explained how his favourite technique works. "Social engineering is the art of manipulation for information – a cyberattack that has minimal technical intervention, relying on specific attributes of human decision-making known as cognitive biases."

He described observing that at one company there was a pizza delivery on Fridays – so he dressed in the pizza firm's uniform, carried a box and was inside the server room in minutes. Here, a quick UV spray of "a chip-and-pin thing from the 80s" revealed which buttons to press.

Woodruff uses techniques such as stealing data from a device while its owner is distracted, placing fake links in emails and dropping USB drives with labels such as "Spring Break". ("Seeing how many guys put that into their machine? It's unreal.")

He even helped Kim Kardashian, warning her publicly about her website's vulnerability. "It was all over the news and then five days later she had a new website," he explained. He probably won't be invited over, he admitted, "but I don't think I like Kanye anyway".

"We might think of hackers as kids sitting in darkened rooms... but they could just as easily be your doctor."
– Jamie Woodruff, technical director, Metrix Cloud

WE ARE ALL SPIES – AND WE ARE ALL BEING SPIED ON

Based on presentations by: **Gordon Corera**, *BBC security correspondent;* **David Ormand**, *visiting professor, War Studies department, King's College London;* **Taavi Kotka**, *government chief information officer, Estonia*

There will be no secrets in the future," BBC security correspondent Gordon Corera stated at the National Security session. "We will all be spies, and will all be spied on."

The question of how nation states deploy technology for defence may not be as old as the computer – but spying is, Corera argued. "The first computer, Colossus at Bletchley Park, was built to aid spying," he pointed out.

Bletchley Park's successor, GCHQ, is under attack for similar snooping, said David Ormand, former head of GCHQ and now professor at King's College London – but he argued that the new Investigatory Powers Act marks "a phase change in the relationship between the secret state and Parliament, with the secret activity of the state now being fully brought under the modern rule of law".

Success, Ormand continued, means balancing strong encryption to secure the UK's future online, while preventing strong encryption helping criminals.

In Estonia, the government is ahead of the UK, the country's chief information officer Taavi Kotka told the room. By moving the state online, Estonia is defending itself against potential invasion and annexation by Russia.

Its expansionist neighbour was thought to be behind a 2007 attack that took an Estonian bank offline – so the country created voluntary cyber-security units through which businesses, citizens and government collaborate. "You can't build 100 per cent safe environments," Kotka admitted. "It's just a matter of time – they will fail."

To deter hackers, he said, Estonia stores information in such small pieces that "even if we lose one piece, we don't lose a lot and all the systems are written in different languages for which there is no repeatable architecture," he explained. "So if you wanted to attack the system, you'd have to find a number of totally different types of attacks."

MEET THE SPEAKER #3:
Moty Cristal, *founder & CEO, NEST Negotiation Strategies*

Sometimes the best approach to a huge data breach is to flirt with the hackers, seasoned negotiator Moty Cristal told the room. "Managing the human factor is key to overcoming a cyber crisis," he explained. He told how during one ransomware hack, he sent emoji and flattering messages to the perpetrators to get them onside.

Cristal is founder and CEO of negotiating consultancy NEST – but he cut his teeth in the Israel Defense Forces, negotiating between Palestinian militants and the Israeli army. In every situation, he explained, you need to know who you're talking to, what they want – and what the risk of no deal is.

He was recently called in by a large financial company which had received ransomware demands from a group claiming to represent the elite Russian state-funded hacking team, APT28. "Once I understood who they were, I began to tease them," he said with a grin.

Later, as he talked down the value of the data APT28 had stolen and tried to negotiate a discount on the ransom, he told them: "Don't take it personally, this is only business."

Eventually he talked them into a cut-rate ransom in return for advice on how to secure the company system against future attacks – crucial in getting the company board onside with the ransom payment. "Negotiation failures can be attributed to the gap between the negotiator and a decision-maker," he explained. "Managing the internal dynamic is sometimes as challenging as the negotiation."

ON THIS YEAR'S STARTUP STAGE

JUDGES' WINNER
Abhirukt Sapru
CheckRecipient, *UK*

Irra Ariella Khi
Vchain Technology, *UK*

Ionut Ionescu
EclecticIQ, *the Netherlands*

Raz Ghafoor
ThirdEye Labs, *UK*

Andrew Martin
DynaRisk, *UK*

Ben Southworth
Yoti, *UK*

Kerri-Lynn Hauck
Fabric, *UK*

Chris Wallis
Intruder, *UK*

Andrew Bud
iProov, *UK*

Nik Whitfield
Panaseer, *UK*

John Yeo
Codebashing, *UK*

Stuart Laidlaw
Cyberlytic, *UK*

Peter Bradley
Torsion, *UK*

Edward Mung
SpearSec, *UK*

NEVER UNDERESTIMATE A HACKER WITH A PLAN

Based on presentations by **Adrian Nish**, *head of threat intelligence, BAE Systems;* **Sadie Creese**, *professor of cybersecurity, Department of Computer Science, University of Oxford*

Hacker gangs now operate with the sophistication of an *Ocean's Eleven*-style heist team, Adrian Nish, head of threat intelligence at BAE Systems, warned as he opened Threat to Enterprise, the day's first session.

He unpicked one complex attack on Bangladesh Bank in February 2016, which targeted $951 million (£773m) from the bank's central reserve. "There was a lot of planning," Nish said. "They started six months before, setting up bank accounts in Manila and Sri Lanka. Then they waited for the perfect moment to strike."

They chose Thursday, February 4, 2016 – Thursday is the end of the week in Muslim Bangladesh and the following Monday was Chinese New Year and a Filipino bank holiday, giving the hackers a four-day window.

"They used just eight bits of code to manipulate the interbank network for sending payments," Nish explained. The gang sent 35 transactions to the Federal Reserve Bank in New York where Bangladesh has its foreign reserves. "Some transactions were blocked, but four were let through, netting $81 million – one of the biggest bank robberies in history."

As Nish and his team unravelled the gang's tactics, they noticed the same code had been used before in a Vietnamese bank the previous year and the Sony Pictures hack in 2014. "We're dealing with professionals who've been trained to make network intrusions, move across networks and get on to sensitive systems," Nish warned. He recommended regular penetration testing and staff training.

For Sadie Creese, professor of cybersecurity at the University of Oxford, staff were also at risk. Her warning against insider threats included a plea for diversity: "Monoculture makes you predictable, and it's important – if we want to become resilient – that we embrace the natural differences we have."

MEET THE SPEAKER #4:
Ian Levy, *technical director, UK National Cyber Security Centre*

Cybersecurity is broken – and it's the cybersecurity industry's fault, Ian Levy, technical director at the UK National Cyber Security Centre (NCSC), said.

"There is no other part of public policy where the tone is set by a group of massively incentivised people," explained Levy, who runs the newly formed branch of GCHQ responsible for keeping the UK safe from online threats. The security industry talks up a culture of fear, then these firms offer "magic amulets" which promise to defend against attack.

"Advanced persistent threats" was a bugbear phrase for Levy, who argued that, since most cyberattackers do the bare minimum to overcome cyberdefences, a better term might be "adequate pernicious toe-rags".

Levy explained how early intervention is key: "Rather than telling people not to click on links within suspicious emails, the NCSC is working on making sure that UK citizens never get those emails in the first place."

To do this, the NCSC is rolling out domain-based message authentication, reporting and conformance on all 6,000 UK government domains. This blocks malicious mail from websites pretending to be government agencies. He hopes this will roll out to the private sector.

If all fails, he said, there's always Levy's own patented amulet, the Air Gap – a piece of hardware that promised to defend against all viruses. Of course it was a joke, he explained. "It was an empty box with a blue light," he told the crowd. "But I had so many enquiries I had to take it offline."

WATCH WIRED SECURITY ONLINE

Visit wired.co.uk to view each of the WIRED Security speakers' talks in full.

WATCH THE SKIES – AND BEYOND

Based on presentations by **Adrian Ludwig**, *head of Android security, Google;* **Ian Levy**, *technical director, National Cyber Security Centre;* **Patricia Lewis**, *research director of international security, Chatham House*

When thinking about the future of cyberattacks, it's time we started worrying about space, Patricia Lewis, research director of international security at Chatham House, told the conference.

Joining her in heading up the Emerging Threats session were Adrian Ludwig, Google's head of Android security, and Ian Levy, technical director at the UK National Cyber Security Centre. Lewis explained that although many satellites orbiting the Earth have on-board computers that allow for remote reconfigurations and software upgrades, their hardware will inevitably fall behind, creating serious legacy issues.

"There are two types of attack that need to be urgently addressed: jamming or spoofing and taking physical control of a satellite," she said. "By taking control of a satellite, it could be turned off or forced to burn up its solar batteries, destroying on-board data."

Reports suggest that states are already developing these cyberattack capabilities, although Lewis argued that governments are probably not preparing to take down satellites with rockets for fear of destroying their own satellites. "But what about a state group with no satellites, or a non-state group who could do this, like terrorists?" she asked.

Finally, she warned against manipulation of global navigational system data, which has affected two US environmental monitoring satellites in 2011 and a US weather satellite system in 2014.

GPS is crucial for migrants and refugees, who use their phones to navigate dangerous and unfamiliar territory, said Ludwig. "Android is what's used when these people are fleeing."

Android is now offering high-level security to anyone, including migrants, he explained. Its SafetyNet system protects data and scans for unsafe apps regularly – and daily in Russia.

Levy went on to explain how the UK government is hoping to extend a similar screening system. "By default, let's protect people," he concluded.

XL CATLIN

MUMMY, WHAT'S A STEERING WHEEL?

Who'd have thought that driverless cars would become commonplace within the next decade? Thanks to our partnership with autonomy software specialist Oxbotica, we're not just investigating the future of risk. We're also asking the right questions and investing in the future of mobility.

For more Forward Thinking, visit **xlcatlin.com**

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WIRED
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Events, new products and promotions to live the WIRED life

Compiled by Anabelle Denford

1 2
3 4

1/ Lab Series MAXELLENCE The Singular Cream

From space to your skin, MAXELLENCE The Singular Cream from Lab Series is a moisturiser like no other: it's infused with extracts from the core of an asteroid. The cream, rich in calcium and magnesium, is formulated to revitalise and revive your skin to recapture its youthful brightness. ***£105 labseries.co.uk***

2/ Paul Smith Anglepoise Type 75 Desk Lamp

The limited edition Anglepoise + Paul Smith lamp is a playful interpretation of the desktop essential. This combination of Paul Smith's signature use of colour and the simplicity of the lamp design is guaranteed to make an elegant addition to any workspace or home. ***£160 anglepoise.com***

3/ Vinaya Altruis X smart bracelet

This smart accessory is designed to help balance your digital life and wellbeing. The Altruis X connects to your phone via an app that filters notifications, allowing you to stay connected, not distracted. This black ceramic model comes with a leather, silicone or metal mesh bracelet. ***From £89 vinaya.com***

4/ Hennessy Very Special Cognac

From the Jaguar E-Type to *Citizen Kane*, there are some classics you just shouldn't mess with. The same goes for Hennessy's Very Special Cognac – a benchmark bottle in the world of spirits. The flavour profile includes citrus fruits, apple and roasted almonds. A favourite with ice or poured neat. ***£28 thewhiskyexchange.com***

WIRED INSIDER'S PICK OF UPCOMING EVENTS

WIRED HEALTH

WIRED Health returns this March at The Royal College of General Practitioners, 30 Euston Square. The one-day event will be filled with health innovations, technologies and new discoveries in the medical sector. Expect more than 20 on-stage talks, startup pitch sessions, excellent networking and a technology exhibition showcasing the greatest game-changing devices coming out of the healthcare space. *March 9, 2017*
wired.uk/health17

WIRED MONEY

WIRED Money will return in May for another day of exploring how new business models and technologies are disrupting the world of finance. Now in its fourth year, the event will tackle topics from Brexit to security, and machine learning to our cashless future. We'll also be running a Startup Stage, with up to 20 businesses pitching to an audience of fintech peers and investors. *May 18, 2017*
wired.uk/money17

WIRED EVENTS FOR 2017

The WIRED events series continues throughout 2017 with WIRED Security returning in the autumn. It's quickly followed by our two-day WIRED2017 flagship event and WIRED2017: Next Generation, our one-day experience for 13- to 18-year-olds. WIRED Retail will also return in 2017. Join us for more powerful insights, trend analysis and network. *For more information, visit wired.co.uk/events*

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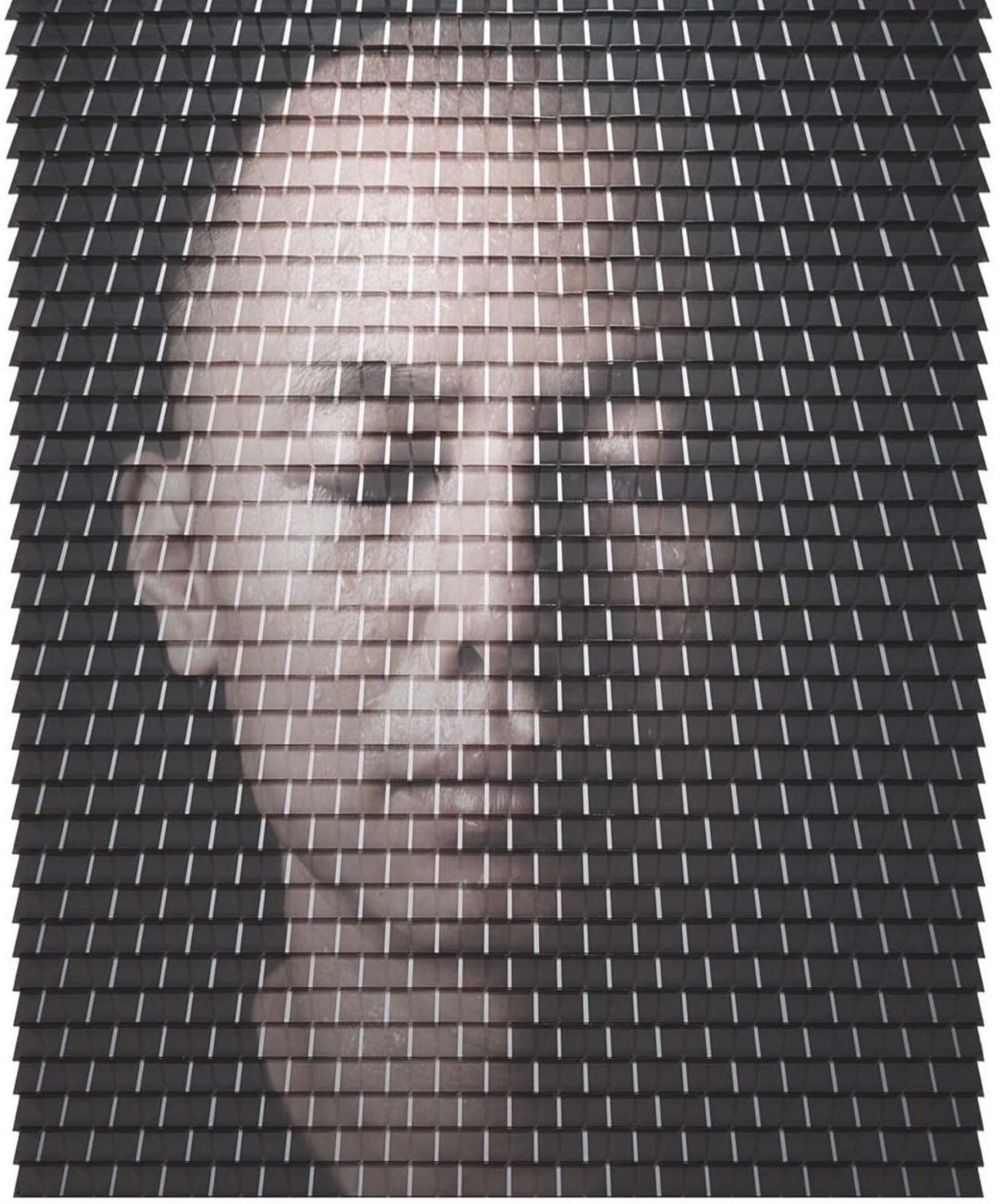
PHOTOGRAPHY: SUN LEE



PORTRAIT FROM THE SHADOWS

>

Wang Ningde creates haunting imagery from fragments of his original photographs

Portrait from the shadows (continued)

Wang Ningde doesn't create photographs – merely the shadows of them. The image on the previous page, from the Beijing-based photographer's *Form of Light* series, consists of the shadows of hundreds of tiny sheets of photographic film.

"Each *Form of Light* work is made from a complete photo that has been calculated and divided into sections on a computer," says Wang. The slices are generated using projection software to estimate angles of a nearby light source. The image is then printed on photographic transparency and cut by hand. "A mistake in any stage of this process will result in failure, so the co-ordination of each step is critical," he says. "The fragments are then reassembled on acrylic board. When exposed to light, the image is revealed."

The film pieces are mounted perpendicular to the gallery wall. As the light in the room fluctuates, so does each image. It becomes lighter or darker and the clarity changes. (A light source is also placed at a specific angle to provide the optimum image when required.) "The light projected on the fragments generates an illusory feeling," says Wang, 45.

Wang's work often plays with photography's traditional form: in addition to documentary images of Chinese life, he makes kinetic sculptures. He began *Form of Light* in 2013 as a meditation on the misleading, dual nature of photography: every picture is a document of a moment but also a shadow of it. "I no longer believe in the documentary ability of photography, nor in its direct correlation with reality," he says. "I now view the photographic world as parallel to, and non-intersecting with, reality."

Wang aims to tour the work this year. "I hope that besides being captivated by the beauty and magic, the viewer will also consider the emptiness of photograph," he says, "as well as the emptiness of our lives."

OF-W *wangningde.com*

JOHN WICK AND THE HEROIC ART OF CAR FU

Director Chad Stahelski launched a startup to create better stunt routines

***John Wick* is back. The cult 2014** movie set a dizzying new standard for fight choreography, with Keanu Reeves playing an ex-contract killer brought out of retirement by the death of his dog. Wick is a balletic killing machine, treating bullets like punches. The reason? The film was directed by Chad Stahelski and David Leitch, veteran stunt artists with *The Matrix*, *The Hunger Games*, *TRON: Legacy* and *The Bourne Legacy* on their collective CVs. The pair's

California-based production company 87eleven Action Design specialises in workshopping original action sequences, which they then pitch to films during the pre-production process.

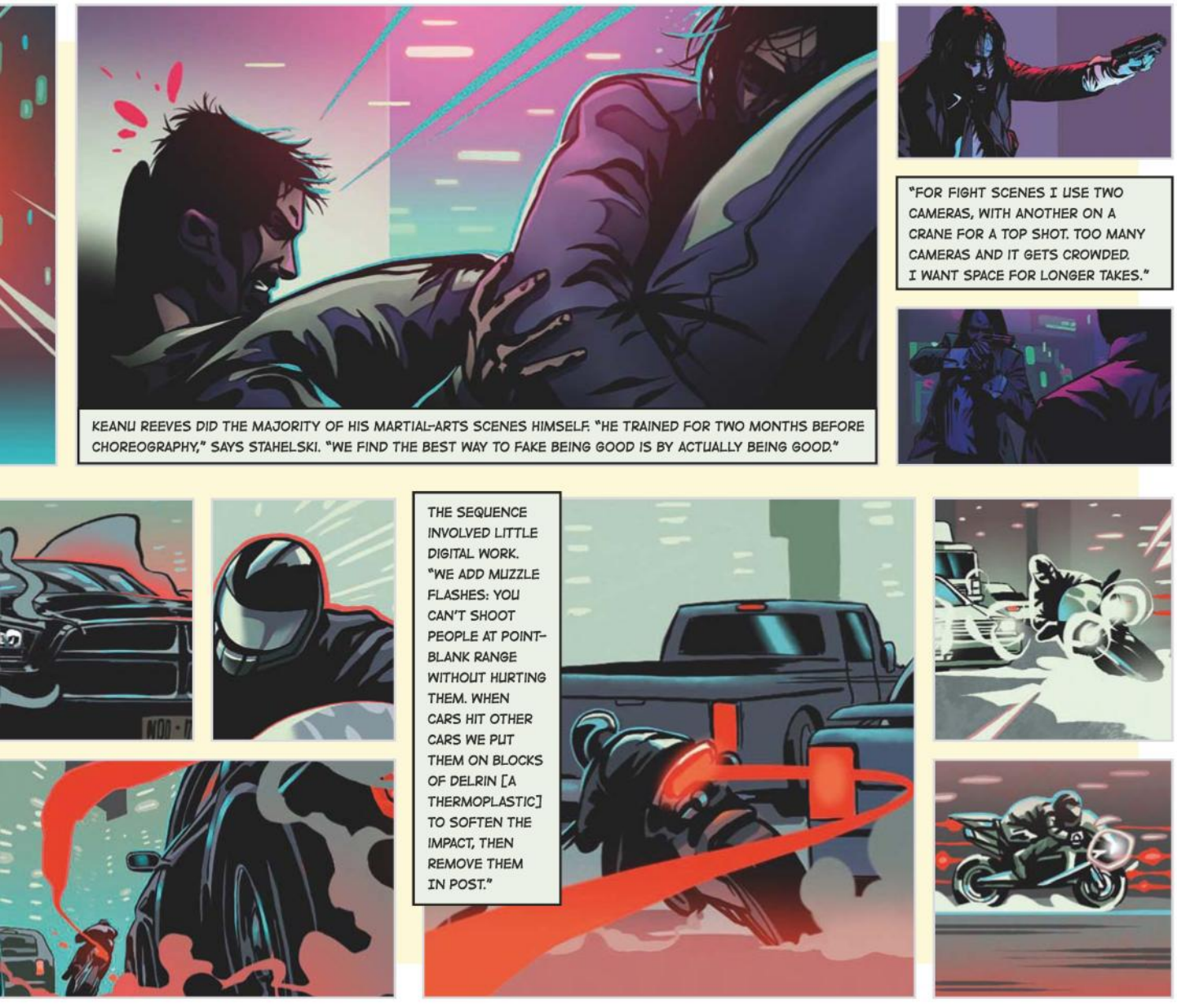
"Most movies will hire a stunt co-ordinator and they'll have six weeks to train an actor and develop moves," says Stahelski, who is also an expert in judo and ju-jitsu. "That's fine, but that's why action scenes are starting to look repetitive. Our martial-arts team works five days a week creating moves that no one's seen before. We'll say, 'Let's try this judo throw tied in with gun fu' [a stylised, firearms-based martial art inspired by Hong Kong cinema] and we'll basically develop our own martial art. We will then piece it together in a cinematic way."

For *John Wick: Chapter 2*, out on February 17, the company decided to push their stunts even further. "The way Wick moves is a character trait," says Stahelski. "We just took it to a higher level. We had Keanu train for four months and expanded the type of weapons he uses. We went deeper into that gun work and mix of jiu-jitsu [a Brazilian martial art] and ju-jitsu, and used longer takes. I want the audience to know it's Keanu doing 98 per cent of this stuff."

Thought gun fu was cool? Welcome to car fu: *Chapter 2* opens with a car-chase sequence that evolves into a full-on brawl in a taxi warehouse as Wick, knocked out of his car, fights several goons while avoiding oncoming cabs. "The sequence took three months to choreograph," says Stahelski. "You don't want to hit Keanu Reeves with a car." **Stephen Kelly** *87eleven.net*

Below: *John Wick: Chapter 2* co-director Chad Stahelski walks WIRED through the sequence's original storyboard in more detail

ILLUSTRATION: ERIC SCOTT PFEIFFER



EAT THIS SPOON; SAVE THE PLANET

When Narayana Peesapaty, an environmental researcher, noticed the plastic cutlery littering his home city of Hyderabad, he sought a solution. The result? Bakey's, a firm making edible spoons from rice, sorghum, wheat flour and water.

Launched in 2011, the spoons didn't sell until a video of the process by positive news site The Better India went viral in August 2015. Within one month, Bakey's took $400,000 (£329,000) worth of orders. It has now has sold five million spoons, which cost £3.50 for a pack of 100. "It took me a while to get people to believe it was possible," says Peesapaty, 50.

Bakey's factory, based 16km from Hyderabad, produces 20,000 spoons a day. The recipe has no fat so the spoons stay solid in hot liquid.

Now, Peesapaty wants to make forks, chopsticks and bowls too. "We want to make plastic cutlery obsolete," he says. **RL-L** *bakeys.com*

PHOTOGRAPHY: ALEX LAKE

MY'S WAY OR THE HIGHWAY

My Helmner is making sure her music is released on her terms

The album is changing: whether it's weekly SoundCloud drops or Drake's curated mixtapes, new artists no longer stick to traditional release schedules. So when Swedish singer-songwriter MY – aka My Helmner – set about creating her debut album, she recorded more than 80 tracks. "I think we're about to lose the album format," she says. "I would like the industry to capture bigger concepts."

MY's music mixes punk with modern pop, experimenting with both genres. "I like to work with a noise and distort something like crazy, or play with sounds that you wouldn't normally put in a pop song," says Helmner. "I want to feel like there are no boundaries."

Growing up in the Swedish coastal city of Oskarshamn, she began recording music at the age of seven. Now 25, she records on the move using GarageBand, Pro Tools and her iPhone to create heady vocals and hooks, while integrating guitars with harmonies and other elements that wouldn't necessarily fit on a regular pop album. Her *Red*-era Taylor Swift style is infused with the Scandi lilt of Mø's electro-pop.

MY's album, due later in 2017, will showcase her prolific output. But that's just the start. Helmner knows that she represents a new breed of artist for whom the output isn't limited to occasional releases, but rather a constant stream. So what should we expect next? "We're still in the experimental stage of our sound," she says. "We'd like to go a bit more extreme." **RL-L** *facebook.com/my.helmner*

Digital extra!
Download the WIRED app to see MY performing at WIRED2016: Next Generation

On being Gaimanesque

Neil Gaiman on *American Gods*' TV adaptation and creating art in uncertain times

After Britain voted to leave Europe in June 2016, Neil Gaiman's Twitter mentions lit up. "It was strange," says the Hampshire-born author. "People would quote me: 'At times like this, you do what Neil Gaiman says, you make good art.'"

Four months later, when Donald Trump won the US election, the messages appeared again. In 2012, Gaiman gave an address to Philadelphia's University of the Arts and described how to respond when things go wrong. "Make good art," he urged. "Do what only you do best." Now he had to follow his own advice.

The day WIRED speaks to Gaiman, 56, it is 28 years and a day since the debut of *Sandman*, the seminal comic-book series that first made his name. Gaiman's distinctive dream logic – the source for everything from screenplays (*Stardust, Coraline – see inset, below right*) to award-winning children's fiction (*The Graveyard Book*) – has shaped the culture. "You don't notice it's happening," he says, "and one day you turn around and it's like, oh fuck, people are using adjectives like 'Gaimanesque' and they seem to mean it." His work is the substrate now, the thing on which other writers build. Take the TV series *Lucifer*, itself adapted from another author's spin-off of *Sandman*. "*Coraline* feels like part of the landscape. *American Gods* as a novel is part of the landscape."

American Gods is Gaiman's coming-to-America story. He moved in 1992 to New York, where he still lives, and he wanted to write about his adopted home. He saw a nation of immigrants: a country, as he puts it, where no one is from. But in place of hopeful fables, the journey was dark and riven with violence. In a plot line that fans describe as prophetic, Gaiman imagined a pair of conmen who feed off chaos. Down on their luck, they devise their biggest con: a plan to fool a country.

Now, after years in development, *American Gods* has been adapted into a television series, airing on Amazon Prime Video in the UK this spring. Gaiman, who wrote the show with *Hannibal* creator Bryan Fuller, is pleased with what he's seen. "It doesn't feel dated," he says. But he doesn't enjoy the prescience of his vision. He sighs: "Even then it was weird. The first signing of the *American* book tour was in the Twin Towers on June 19, 2001. If anything, I feel like I was writing about stuff that was in the wind, and the wind has just been concentrating over the past 20 years."

The same foreboding, this time deliberate, runs through Gaiman's latest work. *Norse Mythology*, out on February 7, retells the myths of the Norse gods – including Odin and Loki, the

Below: Neil Gaiman photographed in Bearsville, New York. He has lived there since 1992 and wrote about it in his novel *American Gods*

two grifters of *American Gods*, who've played the role of villains in Gaiman's work since *Sandman*. The idea germinated eight years ago, when Gaiman was starting a relationship with the musician Amanda Palmer. She was diligently reading his back catalogue, including the novel *American Gods*. "She really hadn't got it and she kept saying, 'I wish this was annotated,'" Gaiman recalls. "I thought it would be interesting just to do a retelling."

Norse Mythology is an odd read, largely because it is so un-Gaimanesque. The tales are told straight, with little embellishment. Although at times Gaiman felt tempted to do his own thing – the absence of the female gods, he says, was especially frustrating – he wanted to "play fair", both with the myths and with his readers. He imagines a curious child coming to them from one of the Marvel films, just as he did aged seven, after reading Jack Kirby's *The Mighty Thor*. "It would give it depth, it would give it weirdness," he says.

The moment Gaiman comes through most strongly in *Norse Mythology* is the end. The Norse gods are fated to die in the final battle of Ragnarök. Gaiman guides the reader with delicacy. "If there was anything I felt like my craft was important to, it was making Ragnarök work," he says. "Using Ragnarök as a weird set of ominous bass notes we keep returning to. And making Ragnarök pay off at the end." It's a sense he has at the moment: of things sliding out of control. "Right now there's a feeling of recognition: 'Oh yeah, I know that, that's where we're at.'"

Gaiman's gloom is grounded in personal experience. A passionate advocate for refugees, he's spent time in the camps in Jordan. He's also experienced online hate first hand, after an anti-Trump tweet attracted "noxious and nightmarish anti-Semitic stuff that I've never encountered before". Gaiman has been using social media since the days of CompuServe. "This," he says, "is new. This is bad. This is weird."

Mythology helps Gaiman keep perspective. The Norse Gods faded. Today's media and tech deities will crumble much faster. "You look at things such as Facebook," he says. "You look at Google, Amazon, *Tinder* and you go: 'One day you will be MySpace. One day you will be one with Nineveh and Tyre.'" He's now thinking ahead, to the possibilities inherent even in disaster: "There is always what comes after Ragnarök. Stuff comes after."

It's hope, of a kind – and Gaiman is apt to be hopeful. "I want people happy," he says. If he has a political message, he slips it in sideways, the way he did in *American Gods*, or in *Neverwhere*, a novel about homelessness disguised as a magical quest. He's working on a new novel; it started out "light and fluffy", he says, then, over the autumn, the tone changed. "It's going to be a lot darker. And that's OK," he says. He's putting in his experience, his desire to create. That's what you do, in uncertain times: make good art. **Rowland Manthorpe**

PHOTOGRAPHY: BEOWULF SHEEHAN. ILLUSTRATION: SAM PEET

McNUGGETS OF STARTUP WISDOM

Out February 10, John Lee Hancock's film *The Founder* tells the entertaining tale of how Ray Kroc turned a family restaurant owned by the McDonald brothers into the world's biggest fast-food chain. Here, WIRED digests the takeaways from Kroc's methods for use in your next startup pitch deck. Olly Richards

THE NAME IS EVERYTHING
Why did Kroc snaffle McDonald's instead of starting his own burger joint? McDonald's sounded homely. Kroc's sounds like it serves swamp meat.

THE CUSTOMER IS ALWAYS RIGHT – UNTIL THEY'RE NOT
Kroc's strategy: make sure your product is the finest quality – until you're so big that people will eat it anyway. Then you can serve what you want.

PUT EVERYTHING IN WRITING
The McDonald brothers claimed Kroc promised a share of all future revenue – but only agreed to it on a handshake. That handshake was worth about as much as they received: nothing.

VISIT THE ISS (NO SPACE SUIT REQUIRED)

Channel Tim Peake with this VR experience

Even in virtual reality, floating 402 kilometres above Earth is terrifying. *Home*, a 15-minute experience created by London-based production studio Rewind, is the closest most of us will get to the real thing. Based on Tim Peake's Nasa and European Space Agency (ESA) training programme, *Rewind* is intended as a realistic recreation of working on the International Space Station (ISS).

To develop the experience, the studio worked closely with Nasa and the ESA. "Nasa has an open-source library of 3D models and plans, so we used that for reference," explains Matt Allen, the company's 30-year-old CTO. "With the ISS model, the airlock and the suits, we wanted to be as accurate as possible."

To build the visuals, the company used modelling packages such as 3D Studio Max and Unreal Engine 4. The narrative, created by the BBC's digital storytelling team, begins on the Quest Airlock of the ISS. After opening the airlock, players must traverse the exterior of the space station – with an accompanying view of Earth below – to a radiator panel. To do this they must use HTC Vive controllers as hands. The sensation is exhilarating, if at times unsettling: Allen's team had to adapt the experience because heights in VR can make viewers squeamish. "We had to tweak the way you move and traverse the outside of the ISS, taking away a few degrees of freedom," explains Allen. "It can be quite nauseating in VR."

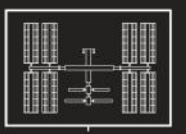
Home won the Audience award at the Sheffield film festival in 2016 and is available now on HTC Vive and Oculus. *Rewind* may have traversed shallow space, but the studio isn't getting complacent. It is branching out into augmented reality with experiences using the Microsoft HoloLens. "VR is a major thing now," says Allen, "but we're always looking forward to the future." The sky's no longer the limit. **RL-L** *rewind.co*

CREATING HOME'S VR SPACEWALK:

HOME START S IN THE AIRLOCK; YOU THEN TRAVERSE ROUND TO A ROBOTIC ARM

LIKE ASTRONAUTS ON THE ISS, YOU MUST CAPTURE AND DEPLOY PAYLOADS

STORMS, METEORITES AND THE AURORA BOREALIS WERE RECREATED AS SEEN FROM ORBIT



THE RENDERINGS OF THE ISS WERE MADE USING NASA'S OPEN-SOURCE LIBRARY OF 3D MODELS AND PLANS

ILLUSTRATION: AXEL PFAENDER

BOOK MYTHS BUSTED

The phrase "Never judge a book by its cover" has been proven by data – partly. Scientists at Kyushu University in Japan have created an artificial neural network to judge more than 130,000 books from Amazon, based on their looks. The programme made some discoveries – light-blue covers tend to indicate diet books; larger covers indicate thrillers – but it only predicted 40.2 per cent of their genres successfully. Conclusion: some clichés shouldn't be doubted. **RL-L**

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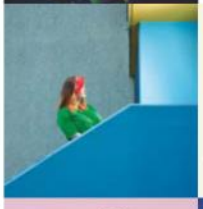
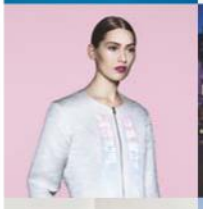
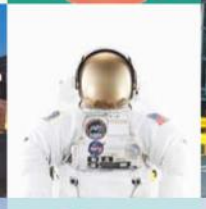


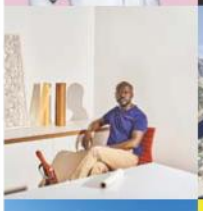
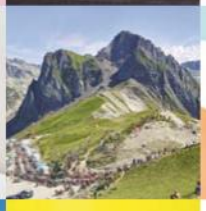









DAILY UPDATES FROM THE WIRED TEAM

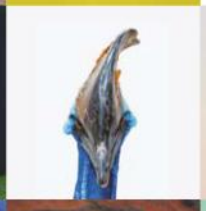



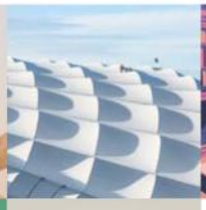





INSIDER ACCESS TO WIRED STORIES





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IT'S ALL IN THE DECOMPOSITION

Daniel Arsham creates modern archaeology from our everyday items

Daniel Arsham's art takes you back in time to the present from a far-flung future. The Brooklyn-based artist fossilises contemporary items – cameras, furniture, clothing, "things we associate with the present," says Arsham, 36, "as if they were crystallised over millennia."

Arsham's work – which spans sculpture, architecture and performance – plays with our sense of time and space. His obsession with archaeology goes back six years, to a trip to Easter Island. "I was watching the archaeologists, thinking about how archaeology is composed," he says. He began to experiment with recasting modern technology in volcanic ash. "I've started to think of eBay as this bizarre Library of Alexandria," he says. When he studies its most popular lists, the site "suggests iconic objects". To create the crystallised versions, Arsham casts a mould of the object; crushed calcite is then pressed into the moulds with a binding agent. "If I add wax to the mould in certain areas, it causes those parts to not bind, so I'm able to control the decay."

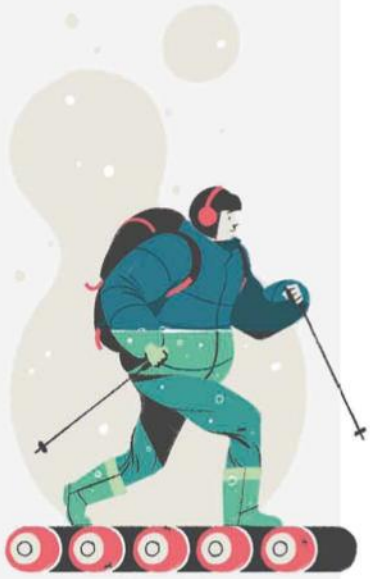
Arsham is almost completely colour-blind: much of his work is monochrome. But recently he has worn EnChroma corrective glasses, allowing him to experiment with a wider gamut: a purple cave of calcified basketballs and, for his HOURGLASS show, opening in February at Atlanta's High Museum, a Japanese Zen garden cast in deep blue. "It allowed me to select a palette and materials that I felt had a very strong resonance," he says.

Upcoming work includes a photo exhibit where 60,000 of his shots will be curated by a Cisco artificial intelligence, which detects the emotion in images. And, if you don't make it to one of his exhibitions, you may encounter his work in the distant future: the calcite sculptures don't decompose unless submerged in water, so "our work will outlast some of these original objects," he laughs. "In a funny way, they may be the last remnant." **OF-W**

danielarsham.com

Digital extra!
Download the WIRED app to see more of Daniel Arsham's work

Above: Daniel Arsham's treatment of a Technics SL 1210 turntable. He has also fossilised keyboards, guitars and a Sony Walkman



CHARGE YOUR PHONE... BY STROLLING

A brisk walk could soon charge your mobile phone – if you're wearing the right outfit, that is. Nanotechnologists at the Georgia Institute of Technology, Atlanta, have created a material that can produce and store its own electricity. "We wanted to utilise the soft fibre-based devices to convert solar energy or motion energy into electricity," says Zhong Lin Wang, 55, who worked on the study.

Using cylindrical dye-sensitised solar cells and nanogenerator fibres which create energy when rubbed together, the material can harvest power from the Sun or its wearer's movement. They suggest it could one day be incorporated in the designs of watch straps, bracelets or even T-shirts.

The bad news? The prototype is still "four to five years" from full production. "Performance and robustness were challenges," says Wang. And then there's the hygiene issues. "Anything you put in a washing machine will be destroyed." In other words: this one's for dry-cleaning only. **RL-L** *gatech.edu*

PORTRAIT OF THE ARTIST AS ROBOT ARM

Dragan Ilić has created an uplifting remedy to his declining agility

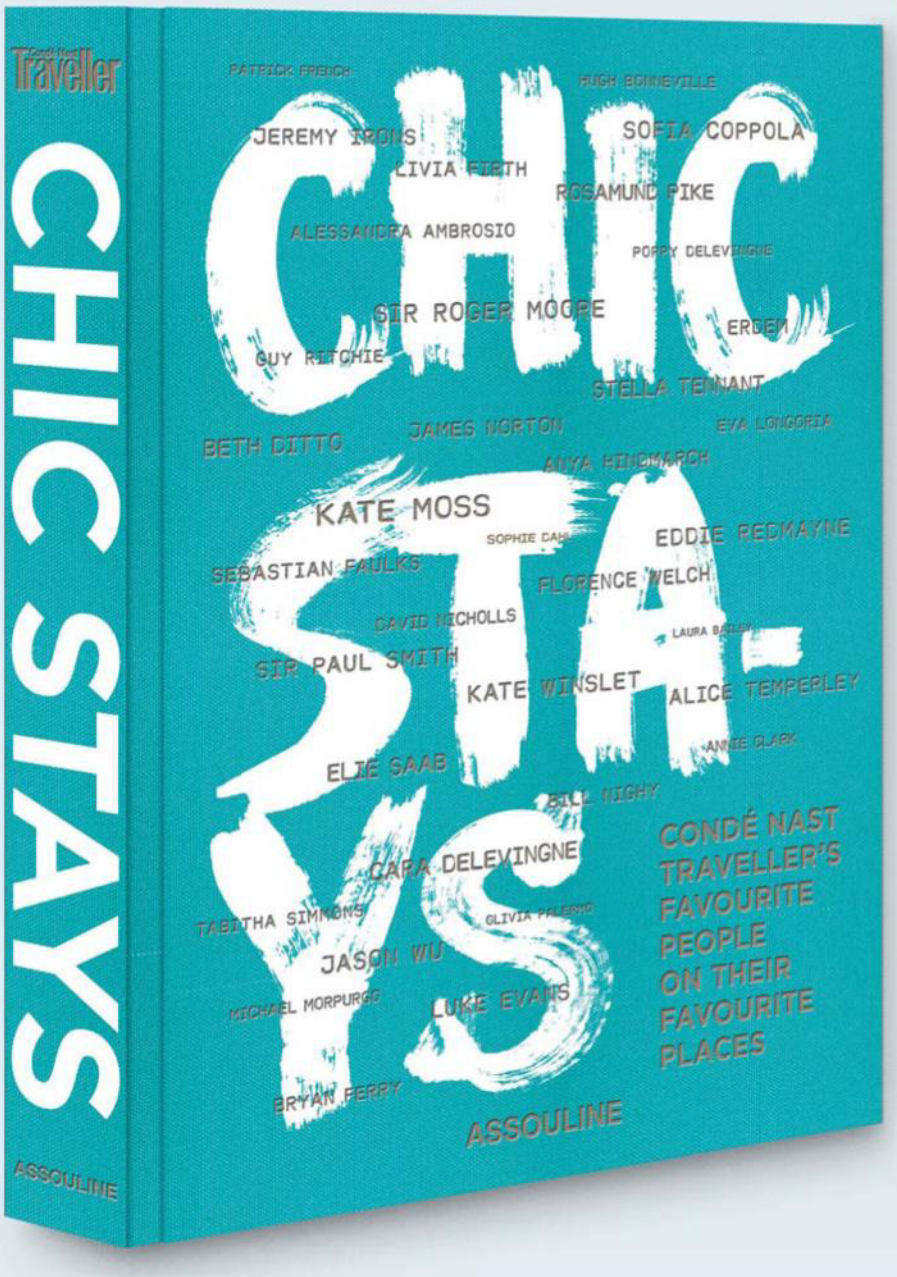
When 68-year-old artist Dragan Ilić realised he was no longer agile enough to create exactly what he wanted, he wasn't deterred. The Serbian artist makes massive abstract works using pencil and paint, filling whole rooms. "When I noticed I had got old and less able, I knew I needed a helper," explains Ilić. "That helper turned out to be a robot."

By using an industrial bot to carry him, Ilić is now able to create unique patterns on large-scale canvases, by pre-programming its movements. He spent 15 years searching for the right machine to suspend him above his canvases before discovering a second-hand Kuka K210+DI that was perfect for the job. Originally used for stacking heavy industrial loads, the £18,000 robot can carry up to 210kg. To create Ilić's pieces, the robot's movements are first programmed according to a pencil drawing made by the artist himself. Once it's programmed, Ilić is strapped, standing, on to the machine, and moved around a canvas at a rate of two to three metres per second. Drawing with markers, paint or pencils, Ilić records his process, eventually creating an audiovisual art piece.

Having debuted his technique at the Ars Electronica festival in Austria in September 2016, Ilić is now pushing the limits of his studio assistant – in occasionally surreal directions. One planned piece involves attaching pencils to the legs of his three pet dogs and lifting them with the machine. He's also working to combine the robot with brain-computer interfaces, to give his thoughts direct control over the robot's movements. In doing so, he's again extending his body – and his mind. "I have been waiting for this for years," he says. WIRED's glad it's given him a lift. **RL-L** *draganilic.org*

Digital extra!
Download the WIRED app to watch the robotic assistant in action

PHOTOGRAPHY: BRANKO STARCEVIC.
ILLUSTRATION: TOMMY PARKER



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A BRIEF HISTORY OF TIME TRAVEL

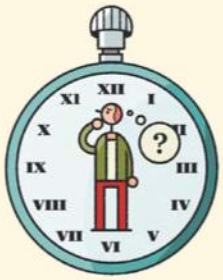
James Gleick's new book explores our (surprisingly new) obsession with era-hopping

Of all time travel's paradoxes, here's the strangest of them all: hop on a TARDIS back to 1894 and the concept didn't even exist. "Time travel is a new idea," explains New York-based author James Gleick, 62. "It's a very modern myth." Gleick's entertaining *Time Travel: A History*, out in hardback in February, quantum leaps from HG Wells's *The Time Machine* – the original – via Proust and alt-history right up to your Twitter timeline. Until we get the DeLorean working for real, fellow travellers, consider it the next best thing. **OF-W**

9th century BCE

THE MAHABHARATA

Time travel appears in Hindu text *The Mahabharata*, and in stories such as Washington Irving's *Rip Van Winkle* (1819) – but it usually only involved a one-way trip. "People fell asleep, and woke up in the future," says Gleick.



1895

HG WELLS'S THE TIME MACHINE

"The idea of time travel with volition, in either direction, didn't arrive until Wells," says Gleick. It explains that time is a dimension – something not widely accepted until Einstein's theories in 1905.

1899

HENRI BERGSON'S TIME AND FREE WILL

Bergson's thesis is published soon after Wells's novel. "Bergson is a friend of Marcel Proust," says Gleick. Soon Proust *et al* are jumping on the idea of time travel to explore free will – and influencing new sci-fi in return.

1930s

TIME CAPSULES

The idea of preserving a time stamp only arose in the 1930s in *Scientific American*. "It's the most pedestrian form of time travel: sending something into the future at a rate of one minute per minute."

1941

ROBERT A HEINLEIN'S BY HIS BOOTSTRAPS

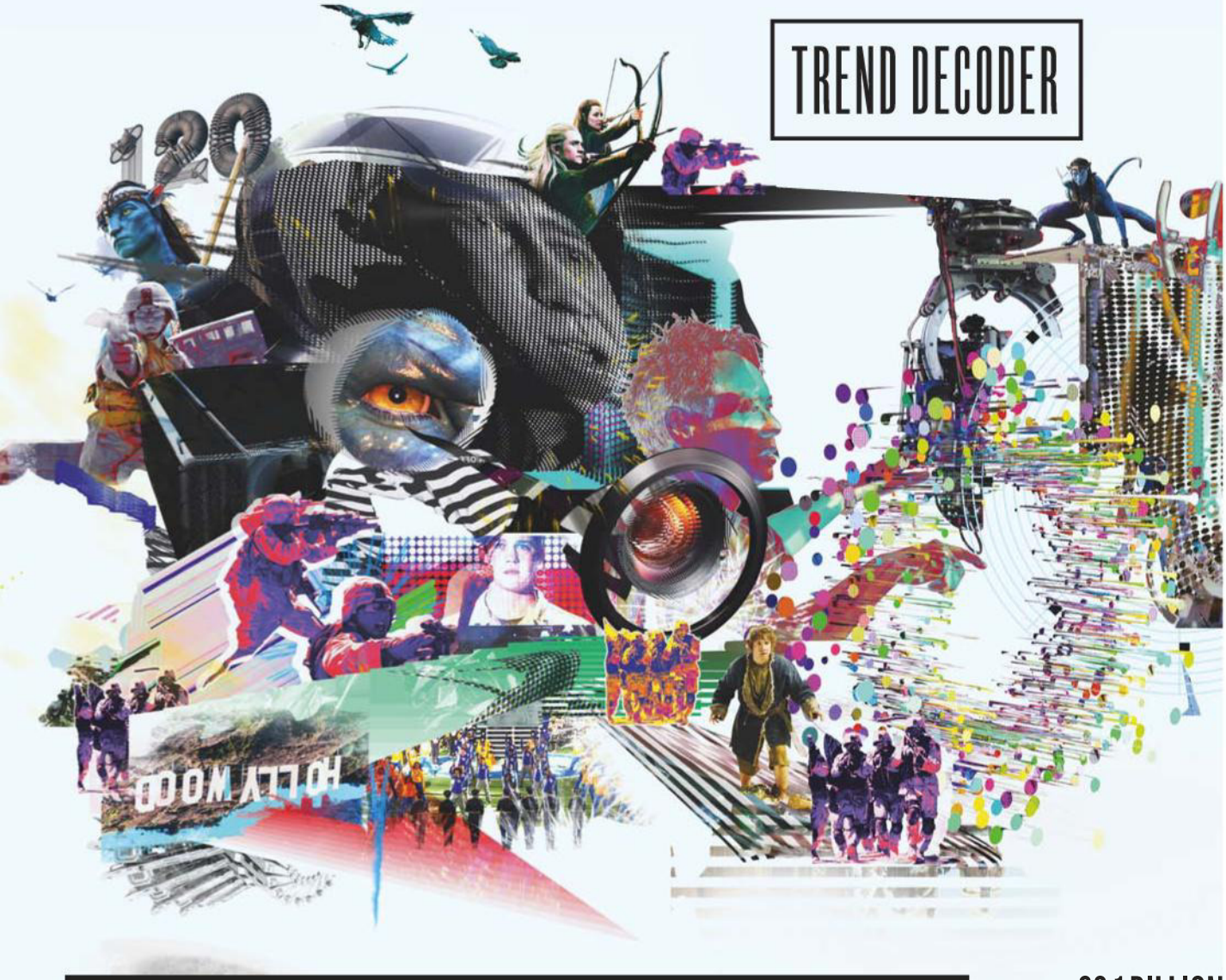
Heinlein's short story, published in *Astounding Science Fiction*, introduces the idea of a character appearing in multiple timelines, meeting themselves amid complex – and funny – paradoxes.

2014

WILLIAM GIBSON'S THE PERIPHERAL

Gleick cites Gibson's unique twist on the genre: "We can't send people, but what if you could send information back to the past?" It's a chilling new take. "It shows how our cultural conception of time is changing."

ILLUSTRATION: NICK D BURTON



HOLLYWOOD'S NEED FOR SPEED

Film is getting faster. Watch Ang Lee's latest, *Billy Lynn's Long Halftime Walk*, out February 10, and you'll be treated to a visual feast: hyper-rich, almost hallucinatory images brought to life with astonishing clarity. The secret: whereas almost all films are shown at 24 frames per second (fps), *Halftime Walk* was filmed at a blistering 120fps. The result is certainly dazzling, but also polarising.

Lee isn't the first to experiment with high frame rate (HFR). In 2012, Peter Jackson's *The Hobbit* debuted 48fps to a decidedly mixed response. HFR appears brighter and more detailed, but it's also unyielding. The falsity of the Shire's props and make-up, to some critics, were exposed under its intense gaze. Lee's use of HFR is more nuanced, however. He uses its hyper-reality for storytelling to mimic the vivid flashbacks of the film's protagonist, an Iraq war veteran. But early reviews haven't been kind.

Nevertheless, HFR is on Hollywood's agenda: James Cameron has declared his interest in using the process in the *Avatar* sequels. And, in September 2016, Netflix released *Meridian*, a short film designed to explore the challenges of streaming at HFR to its subscribers. Expect more to follow. Why? Returns. Studios and cinemas are increasingly competing with our sofas. They hope that the dazzle of HFR and other projection technologies, such as laser and high dynamic range, will provide an additional draw. "I believe that [HFR] is something that audiences will perceive as added value for their experience," says *Avatar 2* producer Jon Landau. "It's about the in-theatre presentation. That's what distinguishes our storytelling from the kind that audiences get at home." If audiences respond enthusiastically, hyper-reality may become the new reality. **OF-W**

£2.1 BILLION

The record box-office takings of 2009's *Avatar*. The film popularised 3D in cinemas; will *Avatar 2* do the same for HFR?

HOW THE FRAME RATES COMPARE

- ▸▸▸ ***Billy Lynn's Long Halftime Walk*** (2017) 120fps
- ▸▸ ***The Hobbit*** (2012) 48fps
- ▸ **Almost everything else** 24fps

"Twenty-four fps came out of the sound era. It was the lowest rate that sound would not distort at and the cheapest that the studios could get away with. Nobody took into account the visual cortex. That's why you see the flicker." Jon Landau

ILLUSTRATION: JAMES DAWE

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SALLY DAVIES
UK CHIEF MEDICAL OFFICER

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HELMY ELTOUKHY
CO-FOUNDER & CEO, GUARDANT HEALTH

Eltoukhy's Guardant Health has created a blood test that can replace tissue biopsies in cancer diagnosis and potentially detect early-stage cancers.

KRIS FAMM
PRESIDENT, GALVANI BIOELECTRONICS

Bioelectrician Kris Famm leads Galvani Bioelectronics, a partnership alongside GSK and Alphabet to develop implantable medical devices.

DAVID HALPERN
CHIEF EXECUTIVE, BEHAVIOURAL INSIGHTS TEAM

David Halpern's team is a UK government and Nesta partnership that applies behavioural sciences to public services.

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THE PEOPLE SYNTHESISERS

Emma Bryce explores how geneticists plan to build the human genome

In July 2015, 100 geneticists gathered at the New York Genome Center to talk about yeast[1]. At 12 million base pairs long, it's the largest genome scientists have ever tried to produce synthetically.

Andrew Hessel, a researcher with the Bio/Nano research group at software company Autodesk, was invited to speak at the event. The audience asked his opinion on which organism should be synthesised next. "I said, 'Look around the room. You've got hardly anyone here and you're doing the most sophisticated genetic engineering in the world," Hessel recalls. "Why don't you take a page out of history and set the bar high? Do the human genome."

This triggered a panel discussion that stuck in Hessel's mind for weeks. Soon afterwards, he contacted George Church, a prominent geneticist at Harvard University, to gauge his interest in launching what would effectively be the Human Genome Project 2.0. "To me it was obvious," Hessel recalls. "If we could read and analyse a human genome, we should also write one."

A year later, his provocation had become reality. In May 2016, scientists, lawyers and government representatives converged at Harvard to discuss the Human Genome Project-Write (HGP-Write), a plan to build whole genomes out of chemically

ILLUSTRATION: GUY BILLOUT

synthesised DNA. It will build on the $3 billion (£2.3bn) Human Genome Project, which mapped each letter in the human genome.

Leading the Harvard event was Church, whose lab is synthesising the 4.5-million-base-pair *E. coli* genome, and Jef Boeke[2], the NYU School of Medicine geneticist behind the yeast synthesis project. "I think we realised the two of us were getting good enough at those two genomes that we should be discussing larger ones," says Church.

A *Science* paper published after the meeting formally laid out the group's proposal: to dramatically advance DNA-synthesis technologies so that the artificial production of genomes becomes easier, faster, and cheaper. Currently, we can synthesise short strands of DNA, up to about 200 base pairs long, but the average gene has several thousand base pairs. Even this limited process is inefficient, costly and slow. But it's vital: in biological sciences, synthesised DNA is the foundation of experiments that drive everything from cancer research to vaccine development. For scientists, it's like working with a blunt yet necessary instrument.

The immense three-billion-base-pair human genome is seen as the project's ultimate goal, dangling like a carrot to drive innovation. Scientists intend to have fully synthesised it in a living cell – which would make the material functional – within ten years, at a projected cost of $1 billion. The fruits of HGP-Write could have wide-ranging, real-world impacts. But in its current form, say the scientists, it's primarily a call for technological advancement in synthetic biology. The May announcement received a frosty reception from some, however. A handful of scientists invited to the event declined to attend, due to organisers' decision not to include the press. Church says they were excluded because of an embargo on the forthcoming paper.

There are bigger concerns: artificial production of genomes raises the ethically unsettling question of gene patenting. Other worries, echoing those that first surrounded the gene-editing technology CRISPR, are of designer humans and parentless babies. "Moving beyond reading DNA to writing DNA is a natural next step," concedes Francis Collins, director of the US National Institutes of Health. He goes on to warn, however, that any project with real-world implications would require "extensive discussion from multiple different perspectives, most especially including the general public". Currently, applications beyond the lab are a distant reality: synthesising a human genome may even prove unworkable. In any case, none of the project's deliverables will be "as exciting or as evocative as a baby", Hessel says. "Some of the things that were said [after the meeting] were so ludicrous that it allowed us to get through that bubble of misinformation and misinterpretation quite quickly."

The immense three-billion-base-pair human genome is seen as the project's ultimate goal, dangling like a carrot to drive innovation

HGP-Write's central goal is to improve synthesis technologies so it's easier to write longer strands of genetic material. DNA is made using software that designs the layout of a strand, followed by machines in a laboratory that use this template to synthesise and assemble it. It's a clunky process that limits production to short stretches of DNA. But Hessel sees the potential for enhanced software allowing more precise genome design and printing tools that, for instance, harness enzymes to build DNA the way it happens in our cells. "If we can achieve this, it should be possible to write large genomes in hours," he says.

Smaller plant and animal genomes could also be synthesised along the way. One major scientific benefit could be the creation of living cell lines for pharmaceutical testing. Whole-genome synthesis would also bring down the cost of gene editing. CRISPR allows individual edits to DNA, but producing a full genome would allow thousands of edits in one go. Church sees the potential of genomes being edited to have multiple-virus resistance, for example.

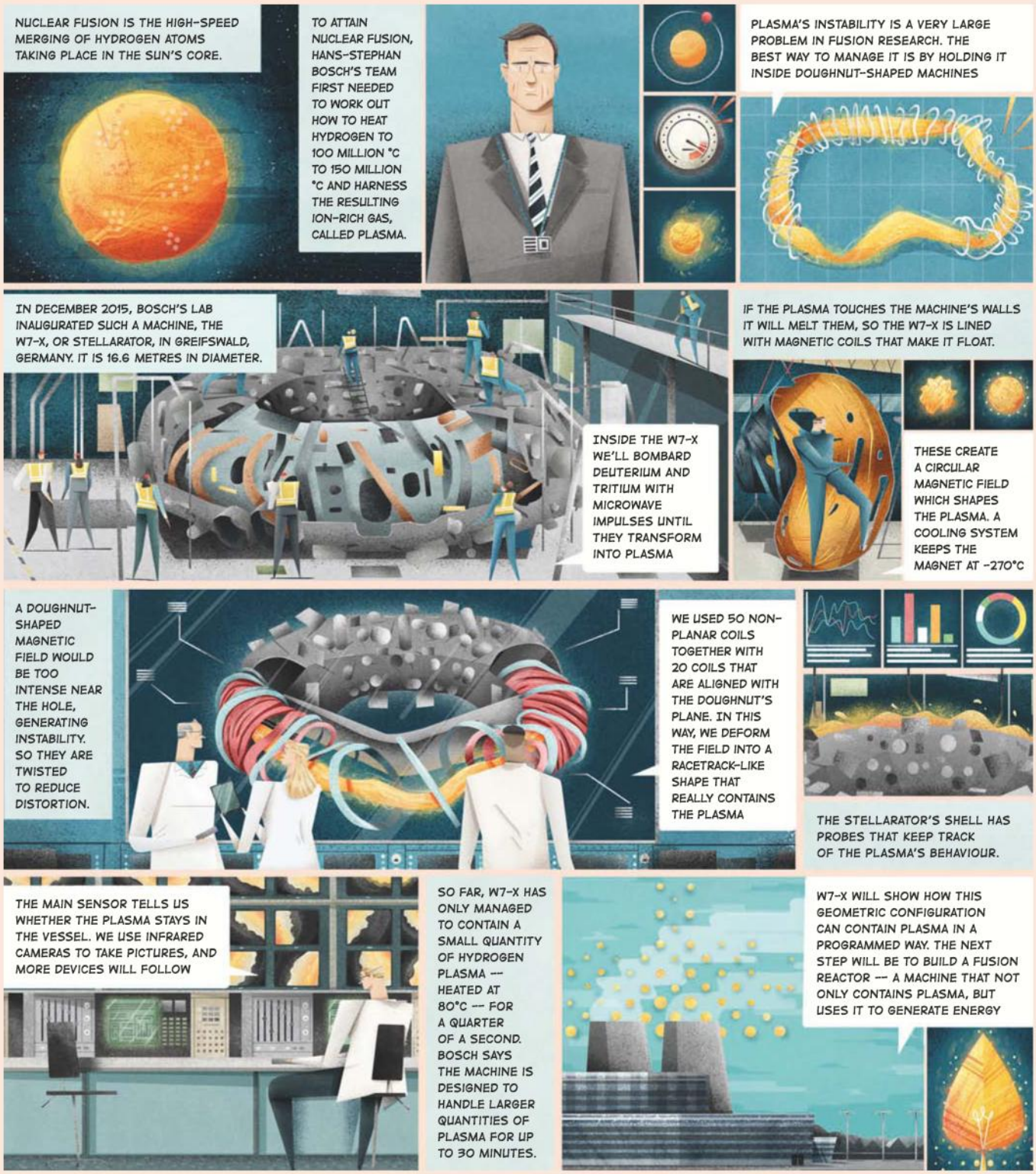
But these are the "byproducts" of HGP-Write, in Hessel's view: the project's true purpose is to create the impetus for technological advances that will lead to these long-term benefits. "Since all these [synthesis] technologies are exponentially improving, we should keep pushing that improvement rather than just turning the crank blindly and expensively," Church says. In 20 years, this could cut the cost of synthesising a human genome to $100,000, compared to the $12 billion estimated a decade ago.

In coming months, scientists will try to take HGP-Write from proposal to project. That depends on funding. Autodesk has pledged $250,000, but organisers want to secure $10 million by the end of 2017. In the meantime, they'll be expanding the HGP-Write conversation. "I want it to be as open and transparent as possible," says Hessel, "and to keep up as much interest in this powerful universal technology, which will enable us to bring our intention into the machinery we call life. And boy, do we need to get good at it."

1. www.syntheticyeast.org
2. Boeke, JD, et al (2016) The Genome Project-Write, Science, 10:1126/science.aaf6850.

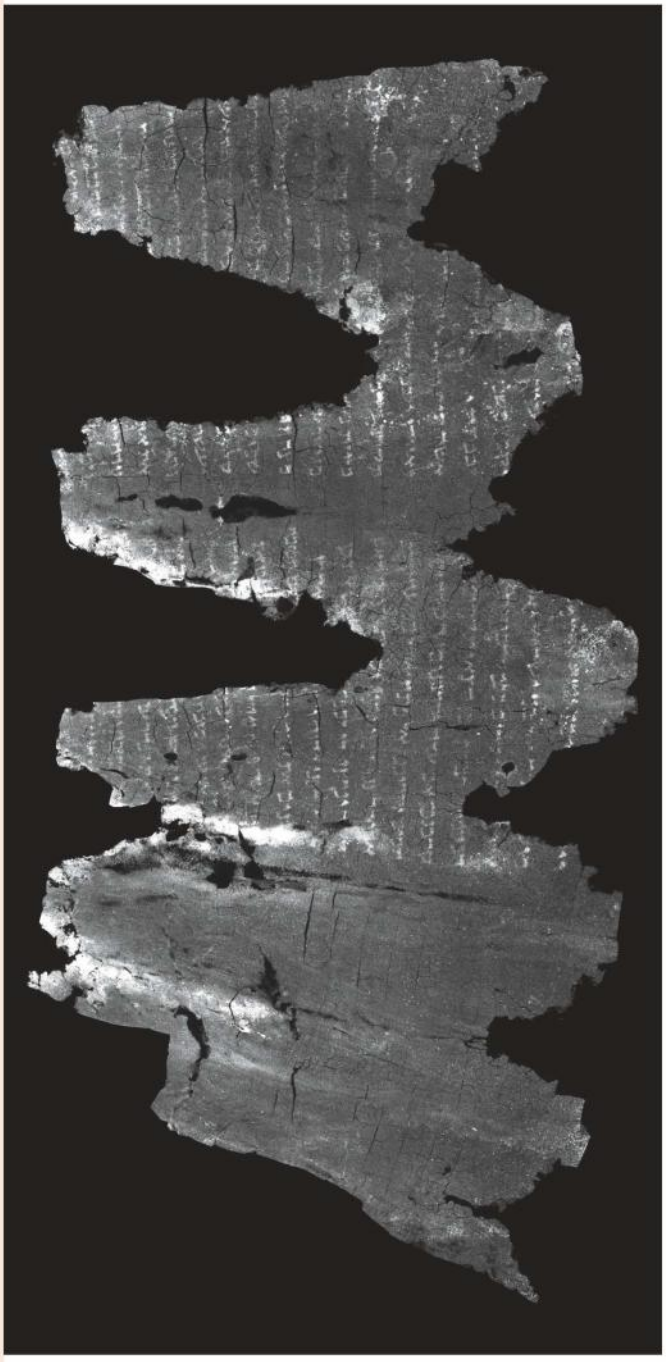
LET'S BUILD A FUSION REACTOR!

Want clean, plentiful energy? Take some hydrogen, heat to 150 million degrees… Hans-Stephan Bosch from the Max Planck Institute of Plasma Physics explains the process. By Gian Volpicelli



*BUT WITH FOOTNOTES. ILLUSTRATION: JOE WALDRON

Deciphered: the scroll that can't be unrolled



Pictured above are segments of the 1,500-year-old En-Gedi scroll, unrolled digitally in September 2016 using a technique called X-ray microtomography. The parchment was discovered in Israel in 1970 but is so delicate that unrolling it manually was deemed too risky. The process was achieved by scanning individual layers of the scroll, before converting them into 3D segments. Then, a second scan was used to detect bright pixels on the surface, which indicated ink. The resulting composite image helped researchers reveal the scroll's Hebrew contents, without once touching its fragile surface. EB

A

mazon Echo, the acclaimed voice-controlled AI device, is built on the technology of a little-known British company, Evi, which Amazon acquired in 2012. Formerly known as True Knowledge, Evi was founded in 2005 by AI aficionado and entrepreneur William Tunstall-Pedoe, who wanted to develop software that accurately interpreted questions and framed more natural, conversational answers.

When it reached the market in 2012, the technology, Evi 1[1], was positioned as a contender to Apple's Siri – although not by Tunstall-Pedoe, 47, who says he set out to build something new, not to compete. Now, 11 years after its inception, he can celebrate Evi's real-world impact. "These technologies are now good enough that they are able to create useful products that change lives and are used daily," he says.

Before Evi's invention, Tunstall-Pedoe, who lives in Cambridge, built his reputation as an AI mastermind and was known for programming computers to crack cryptic word puzzles. He also developed the Anagram Genius software that uses AI to turn words into anagrams. Author Dan Brown used the software to devise the anagrams in *The Da Vinci Code*. (Tunstall-Pedoe is credited in all 80 million copies sold.)

After three years at Amazon, Tunstall-Pedoe recently left to pursue other AI projects. Here, he speaks to WIRED about where voice recognition is going – and what he'll do next.

1. *www.evi.com/technology*
2. *www.williamtp.com/crosswords*
3. *www.aaai.org/ojs/index.php/aimagazine/article/view/2298/2160*
4. *www.pewinternet.org/2014/08/06/predictions-for-the-state-of-ai-and-robotics-in-2025*

VOICE RECOGNITION

Q & A
HEY ALEXA, WHO CREATED YOU?

William Tunstall-Pedoe built the voice AI behind Amazon's Echo

WIRED: Before building Alexa, the AI that underpins Echo, you built an AI that could solve cryptic crosswords. How did this lead to Evi?
William Tunstall-Pedoe: It sounds trivial in comparison, for the size of the problem, but solving cryptic crosswords is a classic AI problem in many ways. It's something computers find very hard, and it requires intelligence. In terms of world impact it's obviously very small, but I was very proud of the technology[2]. The origins of Evi are about a desire to apply these technical skills and understanding to much bigger problems that can affect the lives of billions of people. For instance, the way we operate computers, with buttons or custom interfaces or guessing keywords, for me is not the way that computers are going to work in the future. Surely the most natural way to operate a computer is just to ask it for what you want? That vision is what drove me to found Evi.

What is it that makes Evi competitive as a technology?
One of the big unsolved problems in AI is the ability to understand natural language. The reason search engines still largely work with keyword search, statistics and snippets of text is that the technology doesn't understand what's in a document. There's no deep understanding that comes from reading a document. We haven't solved that problem, but the knowledge that powers the Evi platform is a knowledge base of structured data, including common-sense knowledge, that's in a form computers can understand[3]. So it's not going to a collection of documents – it's not like a search engine.

The other thing that's pretty unique is its ability to reason with knowledge. So we can take a question that has never been asked before, find multiple facts in the knowledge base and chain them together, combining them to create new knowledge that's needed to answer. Our ability to exploit that knowledge base is where the power comes from. This results in many more of the user's questions being answerable than would otherwise be the case.

What are your predictions for how this will this change our reality?
In ten years, people will expect all technology to respond to voice. In every building and vehicle, a computer system will respond to spoken requests and control the technology. Light switches and other controls that we see today may still be present, but will just be the manual alternative. People will also take for granted instant access to all their private data and all human knowledge, just by asking. It's coming sooner than people might realise.

As our idea of intelligence changes and refines, surely the definition of AI will evolve too?
Basically, there is one object in the Universe that everybody acknowledges is intelligent, and that's the human brain. So we have one reference point for what intelligence is. Computers are built in a completely different way to brains, though there is quite a bit of work now trying to merge cognitive science and AI, looking at how neurons work and taking inspiration from that. A lot of the recent big advances in artificial intelligence, such as those in computer vision, have come from what's known as deep neural networks, which are very much inspired by the way the brain works.

So, mimicking the human brain should be AI's ultimate goal?
To be clear, there are things that computers can do way better than the brain can do. Nobody remotely challenges a computer's ability to do arithmetic better than a human. So it's not so much drawing level with the brain. It's about creating computer systems that surpass what people can do, for the benefit of people.

What's next for you?
AI is pushing the boundaries of what's possible with computers[4]. I'm looking for the next really big thing, that will positively impact billions of people. That's where my focus is. I am keeping an open mind for exactly what that will be. I hope to settle into something new in a few months' time. **Emma Bryce**

ILLUSTRATION: ADAM AVERY

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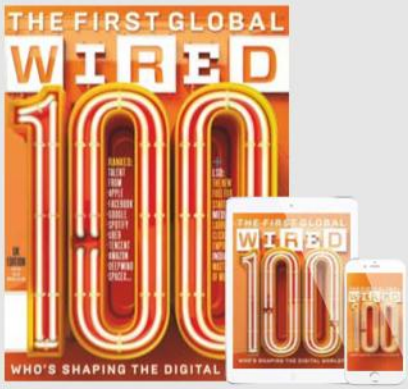
11.16 WHERE NASA GOES NEXT

10.16 THINK BIGGER – DESIGNING THE FUTURE



08/09.16 TOP 100 RANKED TALENT – WHO'S SHAPING THE DIGITAL WORLD?

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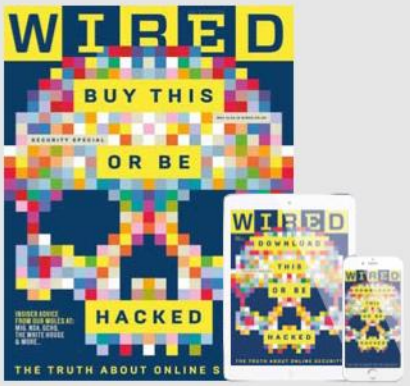

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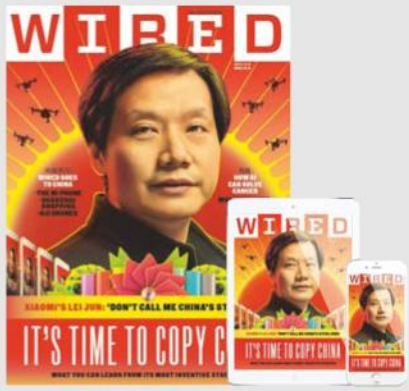

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03.16 THE FUTURE OF FOOD – FEATURING NOMA'S RENÉ REDZEPI

01/02.16 STAR WARS – J.J. ABRAMS ON REBOOTING AN ENTIRE UNIVERSE

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The results are in.

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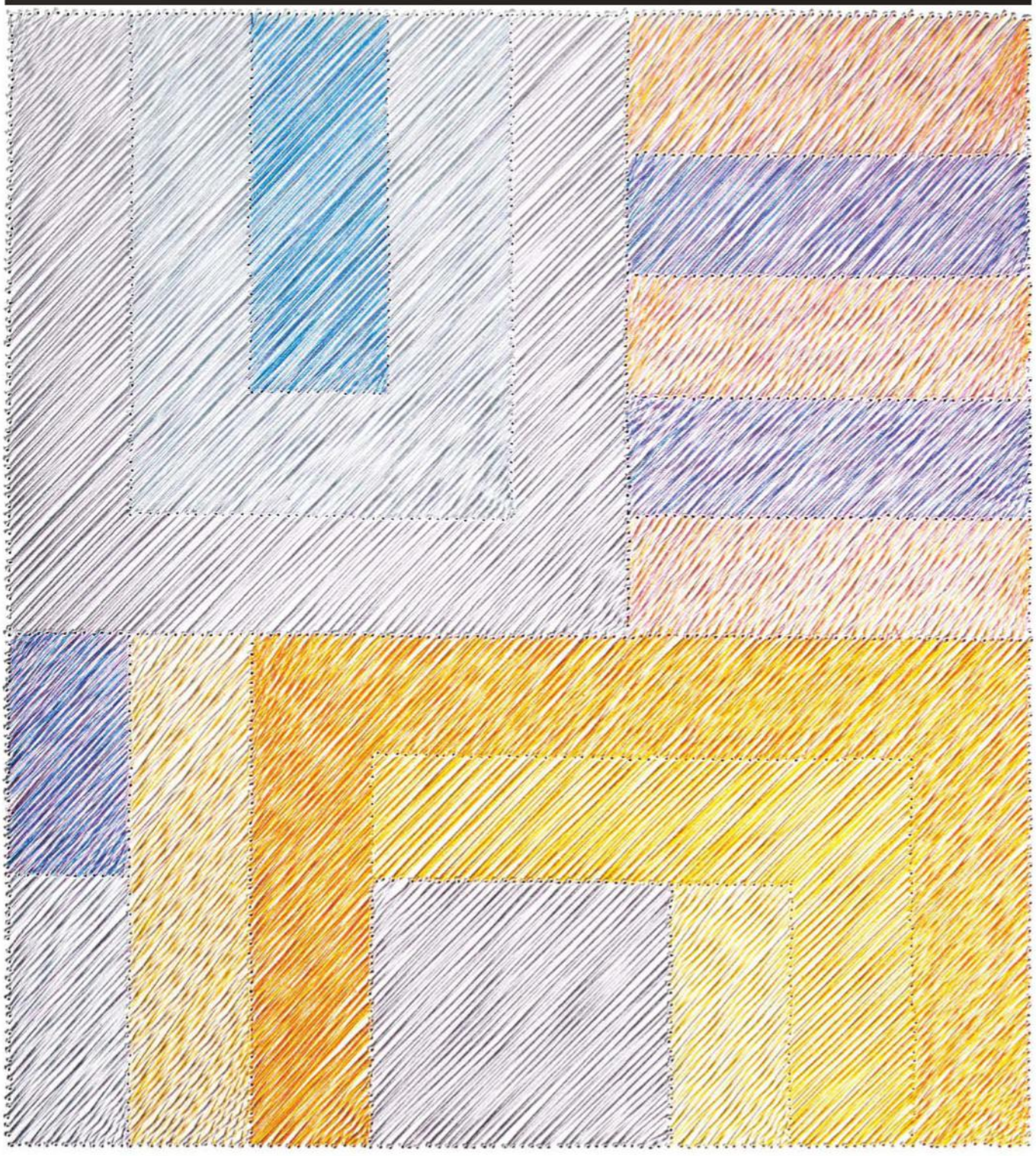


PHOTOGRAPHY: ROGER STILLMAN. CREATED BY VICKY LEES BY PUNCHING HOLES 1MM APART ON A PIECE OF PAPER AND WORKING ACROSS IT WITH NEEDLE AND THREAD

"For 2,500 years we've been taking our time thinking about these questions. Suddenly it's urgent." Stephen Cave, p96

EARTH'S GUARDIANS ARE HERE TO SAVE US

We hate to upset you, but asteroid strikes, rogue AIs, autonomous weapons – and maybe a despotic politician or two – could just wipe out our civilisation. Thankfully, some plucky UK-based scholars are leading the way in tackling existential risk

By **Richard Benson**
Photography: **Nick Wilson**
Illustration: **Señor Salme**

Pictured, left-right: Julius Weitzdörfer, research associate, Centre for the Study of Existential Risk, Cambridge; **Beth Barnes, co-founder, Future of Sentience Society, Cambridge;** Stephen Cave, executive director, Leverhulme Centre for the Future of Intelligence, Cambridge; **Anders Sandberg, author and futurist;** Huw Price, Bertrand Russell professor of philosophy, University of Cambridge; **and Jane Heal, committee member, Centre for the Study of Existential Risk, Cambridge.** *Pictured in the Great Hall, Clare College, Cambridge*

ONE WINTRY EVENING IN NOVEMBER 2016, AN INTERNATIONAL GROUP OF 50 SCHOLARS GATHERED

at a candlelit dinner in the 14th-century Old Library at Pembroke College, Cambridge, to discuss grievous threats facing the world's civilisations.

An eavesdropper in the shadows playing on the wood-panelled walls might have heard Shahar Avin, an Israeli software engineer and expert in the philosophy of science, discussing the coming dangers of artificial intelligence ("It won't be about the Terminator! More likely an algorithm selling online ads, which realises that it can sell more if its readers are other robots, not humans"). Or perhaps Julius Weitzdörfer, the German disaster specialist looking after the legal fallout of the Fukushima catastrophe, analysing the implications of Donald Trump's presidency ("It will make people aware that they need to think about risks, but, in a world where scientific evidence isn't taken into account, all the threats we face will increase"). At another end of the table was Neal Katyal, an American lawyer who was acting solicitor-general under Barack Obama, and who represented Apple in the San Bernardino decryption case. He explained how "law lag", the inability of legislators to keep up with technological change, was weakening governments' power to protect us.

This was not a scene from a new *X-Men* movie, but an event organised by two Cambridge institutions: the Centre for the Study of Existential Risk (CSER, commonly referred to as "caesar") and the Leverhulme Centre for the Future of Intelligence. For them, it was a fairly ordinary evening, in this case following a lecture by Katyal. The apocalyptic talk is standard: both bodies are among a small group of organisations in the UK and US which employ highly educated academics, scientists, lawyers and philosophers to study existential risk.

Existential risk, known by practitioners as X-risk, groups together hypothetical future events that could bring about global catastrophe, at worst the end of human civilisation or the extinction of humanity. The threats can be subdivided into anthropogenic, or man-made (nuclear war, climate change), and non-anthropogenic (asteroids, volcanoes, hostile extraterrestrials), and one that gets the most attention, and which began to catalyse the new discipline about ten years ago – artificial intelligence. Philosopher Nick Bostrom initiated the movement when he set up his Future of Humanity Institute (FHI) in Oxford in 2005, prioritising his belief that the potential risks of AI were too great to ignore. The Centre for the Future of Intelligence (CFI) was set up mostly to co-ordinate X-risk researchers in Oxford, Cambridge, Imperial College, the Future of Life Institute (FLI) at MIT, the Machine Intelligence Research Institute at the University of California in Berkeley and the virtually located Global Catastrophic Risk Institute (GCRI). Cambridge also has an undergraduate organisation, the Future of Sentience Society, co-founded by computer-science undergrad Beth Barnes, who also works with CSER in the role of "student collaborator".

AI has been the subject of fantasy since the industrial revolution, but the 21st century's rapid growth in computing power has prompted anxiety in some of the world's most rational, informed and intelligent minds. In January 2015, Stephen Hawking, Elon Musk and Google's director of research Peter Norvig were among dozens of experts who signed an open letter calling for more research on AI's potential impact on humanity. The letter had initially been drafted by the Future of Life Institute, for circulation among AI researchers. Concern has only grown since: Martin Rees, the astronomer royal, Cambridge cosmologist and the third co-founder of CSER, believes X-risk research is essential because, although Earth has existed for 45 million centuries, ours is the first in which a single species holds the future of the biosphere in its hands.

X-risk commands increasing interest within the technology industry. CSER was set up partly with the support of Skype co-founder Jaan Tallinn after he met Huw Price, Bertrand Russell professor of philosophy at Cambridge, at a conference and found they shared concerns about AI and other threats. Tallinn became worried after reading Eliezer Yudkowsky's writing about AI, and sought to bring together minds from diverse areas of study to create a new academic discipline. "There is a fertile area of scientific study that can be done at the intersection of physics, computer science and philosophy," he says. "You can make a philosophical argument, but use a mathematical model that keeps you in check and stops you going off talking nonsense, which most philosophers do, because they say things that only bottom out in their intuitions, and intuitions are flawed. If you can make a philosophical argument that bottoms out in computer code or a mathematical model, that's a very solid foundation. At the same time, philosophy can make science consistent and give its findings a framework and direction."

Bostrom makes a similar point when he says the FHI "formulates questions that one might need to answer if future technologies transform the human condition". One example is that we might easily agree that robots should share human values. But how do we agree what those values are? As Stephen Cave, CFI's executive director, notes: "For 2,500 years we've been taking our time thinking about these questions and suddenly it's urgent. It's very exciting."

X-risk can stretch the bounds of the imagination. Anders Sandberg, a polymath probability theorist at the FHI, discusses the possibility that someone might summon a demon to end the world ("Can you really say the probability is zero? Some would say yes, but we ask, how can you be certain?"), and others are careful to consider the limits of human cognition (How can we know that millions of previous human worlds were not wiped out in the past by risks that may seem very remote to us?).

More importantly, points out CSER executive director Seán Ó Héigeartaigh, most of the work has practical applications. CSER management committee member Jane Heal, for example, studies "how we can distance the reflective, detached part of the self from the hubristic animal part of it, so that we can band together to make legislation that might reduce climate change."

Does thinking about all these questions keep such academics awake? Bostrom laughs: "People always ask that." Sandberg says his standard answer is, "I sleep very well at night because at least I'm doing something about it." Tallinn is more philosophical: "In truth, it makes me appreciate the world a lot more. If you have a sense that we might be the last generation after four billion years of evolution, it makes you want to do something about it, but it also makes you really thankful to be alive in the first place."

TEN THREATS THE X-RISK TEAMS ARE TAKING SERIOUSLY:

1. ARTIFICIAL INTELLIGENCE TAKES OVER THE WORLD

Machines developing intelligence superior to, and autonomous from, human beings is one of the most important concerns in the X-risk community. Bostrom says that if we experience a rate of change comparable to the industrial and agricultural revolutions, the AI train "might not pause or even decelerate at Humanville Station". He predicts that machines will attain 90 per cent of human-level intelligence by 2075.

The other reason for the urgency, as Tallinn, who is also the co-founder of the Future of Life Institute, points out, is that the AI risk increases all the other risks. In other words, there is a risk that intelligent robots will run wild and screw up the environment, or cause a nuclear winter.

However, sci-fi scenarios are not on the agenda. If the community has a catchphrase, it is: "This isn't about the Terminator." If you can imagine specific, tractable risks, many of them cease to be risks because it's possible to take preventative action. The challenge is to imagine what we can't imagine and deal with it.

The research in this area ranges from the philosophical (should we align AI moral values with those of humans? In which case, what are our moral values?) to the direct and practical (how exactly should autonomous weaponry be regulated?). It is also controversial. Some AI researchers argue that it doesn't pose an existential threat. The X-risk argument isn't that it does, but that it could, and therefore is high on the organisations' threat agenda.

LIKELY DATE OF OCCURRENCE: 2075
X-RISK PRIORITY: VERY HIGH

In 2014, Stephen Hawking said: "Full artificial intelligence could spell the end of the human race"

One possibility is the disgruntled individual who might create or steal a virus and travel around the world releasing it

2. SYNTHETIC BIOENGINEERING BECOMES A THREAT TO HUMANITY

Along with AI, synthetic biology is one of the two most-studied global catastrophic risks. It is an area given new urgency by the controversy over "gain of function" experiments. These involve taking a known pathogen and adding extra, risky functionality. For example, in 2011, virologists Ron Fouchier and Yoshihiro Kawaoka created a strain of the bird flu virus that could be transmitted between ferrets. This was done in order to better understand the conditions in which the virus might develop transmitability in the wild. Such experiments can head off certain risks but create an arguably greater one, in that the modified organism might escape the lab and cause a global pandemic.

The risk here is particularly great because it is self-replicating. Whereas a nuclear explosion is localised, in our highly connected world a synthetic, incurable virus could spread around the planet in days. In the past, natural pandemics such as the black death have killed millions and effected wholesale social changes. In the 21st century, advanced biotechnology could create something that makes the black death look like a nasty cold.

The FHI has studied the "pipeline risk" for how such viruses might escape. One possibility is the disgruntled individual, perhaps a lab employee, who might create or steal a virus and travel around the world releasing it. Researcher and author Anders Sandberg is working on a paper exploring the motives of people who, in a Bond-villain mould, want to destroy humanity. "It's hard going actually because relatively few people want to do it. There is very little source material," Sandberg says. This has led him to analyse the extent to which religions and cults might sanction mass murder (most don't, according to Sandberg). When CSER carried out similar research, it led to an important, practical present-time insight: biotech labs have no provision for psychological profiling of their employees.

Sandberg suspects that because of the divergent conditions that would need to coincide, the "lone person" scenario is far less likely than "a disgruntled post-doc, or a laboratory accident due to a biotech startup cutting corners".

LIKELY DATE: TODAY
PRIORITY: VERY HIGH

'It's possible to imagine a world where you wake up in the morning to news that another list of cities has been destroyed, and no-one knows who is behind the attacks.' Jaan Tallinn

3. AI-EMPOWERED WEAPONS SEIZE CONTROL AND FORM A MILITIA

South Korea currently maintains the border with its northern neighbour using Samsung-built robot sentries that can fire bullets, so it's safe to say autonomous weapons are already in use. It's easy to conceive future versions that could, say, use facial-recognition software to hunt down targets and 3D-printing technology that would make arms stockpiling easy for any kleptocrat or terrorist.

As ever, there is a paradox. The cold war nuclear arms race involved states building big bombs (blast areas had to be maximised because the targeting technology was so poor) and using human troops who suffered and acted irrationally. Robotic arms allow for specific targeting and robot soldiers would not suffer or intimidate locals.

However, they will also be so small and cheap that ownership will be decoupled from statehood. The most dystopian scenario is that military power would become so removed from the size of a state that, as Tallinn says: "You might have five guys with two truckfuls of tiny automated weapons taking out whole cities. It's possible to imagine a world where you wake up in the morning to news that another list of cities has been destroyed, and no one knows for certain who is behind the attacks."

Stuart Russell, a computer-science professor at the University of California, Berkeley, worries that an arms-race mentality will kick in before rational debate and consensus-building leads to the UN ban of autonomous weapons currently under discussion. Russell recalls hearing a US military figure say at a conference, "Bring it on. We already have stuff that China can only dream of."

If that seems scary, consider too that a new arms race could speed the development of risky AI, including machines capable of acquiring arms.

LIKELY DATE: **ANY TIME**
PRIORITY: **LOW**

4. NUCLEAR CONFLICT BRINGS ABOUT THE END OF CIVILISATION

Although nuclear conflicts are far less discussed now than during the cold war, many thousands of nuclear weapons still exist, and there are serious tensions – in Kashmir, Taiwan and Ukraine, for example – between nuclear states.

The GCRI studies the subject closely, paying particular attention to the possibility of an accidental war between Russia and the US. The countries own 90 per cent of the world's nuclear arsenal between them. An accidental war happens when one side mistakes a false alarm for a real attack and retaliates with an actual first strike. For 90 per cent of the scenarios the GCRI studied, the annual probability was between 0.07 and 0.00001. The 0.07 figure means that, logically, an accidental nuclear war could occur on average every 14 years.

Radiation from nuclear strikes is not necessarily a threat to the whole of humanity, just the sections of it unlucky enough to be targets. The risk comes from the nuclear winter that could occur if the bombing of enough cities (roughly 100) sent a soot cloud into the stratosphere, blocking the Sun's heat and reducing Earth's temperature. (The "nuclear" prefix here is a misnomer, because any explosion could cause this were it big enough. Some scientists say wildfires already cause localised "winters" that reduce the Earth's temperature by a degree or more.)

The resulting fall in temperatures could reduce food production in the affected areas. If this were to occur in the US, Russia and Europe, the decrease in food supply could be sufficient to trigger the collapse of the remaining intact societies around the world, and thus bring about the end of civilisation.

LIKELY DATE: **ANY TIME**
PRIORITY: **LOW TO MEDIUM**

5. EXTREME CLIMATE CHANGE TRIGGERS A COLLAPSE IN INFRASTRUCTURE

You may be surprised to learn that, for X-risk scholars, climate change is not classed as an urgent problem. For instance, the FHI used to refuse to deal with it because "it's too small a problem," according to Sandberg. That's partly because there are already so many others researching the subject and the fact that climate change is risky is well established – but also, paradoxically, because there are too many unknowns. "It's possible that this century we'll get technology that will fix climate change," Sandberg says. "But then again, we might also get technology that makes it much worse. We don't know how much temperatures will change as a result of human activity, so it's actually very hard to model predictions accurately."

2016 was on course to be the hottest year on record, according to the World Meteorological Organisation

Many of the potentially disastrous effects commonly associated with climate change are of little interest to those studying X-risk. However, the greatest risk, barring a temperature rise that causes people to die of heatstroke *en masse* (very unlikely), lies in its potential to trigger the collapse of human and natural infrastructure – for example, a species dying out and causing the collapse of an ecosystem through knock-on effects. In other words, what could wipe us out is the resultant pandemics or nuclear wars over dwindling resources.

This kind of catastrophic knock-on effect is known as systemic risk, currently the subject of collaborative research by Sandberg and the Global Catastrophic Risk Institute in New York.

LIKELY DATE: **ANY TIME**
PRIORITY: **LOW TO MEDIUM**

6. AN ASTEROID IMPACT DESTROYS ALL TRACES OF LIFE

Earth would be hit by small asteroids constantly were it not for the atmosphere, which burns up anything less than ten metres in width. This is convenient, as even a ten-metre rock builds up kinetic energy equivalent to that of the Hiroshima nuclear bomb. The planet is hit by an asteroid or comet measuring more than ten metres once or twice every 1,000 years. Every million years an asteroid spanning at least one kilometre will also hit Earth, which can be enough to affect its climate and cause crop failures that would put the population at risk.

The really serious, existential-threat-level strikes, such as the 180km Chicxulub impactor, which wiped out the dinosaurs around 66 million years ago, come once every 50 to 100 million years. That may be enough to cause worry, but it's reassuring to know that a) astronomers keep a close eye on larger objects posing a danger to Earth, and b) there is a whole interdisciplinary community of scientists working out what to do if they get too close. ("It's a pretty wonderful community actually," Sandberg says.)

Astronomers look for asteroids, mathematicians calculate their orbits, geophysicists think about impacts and consequences and space engineers work out the best ways to deflect one. Possible tactics include: painting the asteroid white so the reflections of solar wind radiation drive it out of orbit; using gravity tractor spacecraft to push it away; crashing spacecraft into it; and the use of lasers or thermonuclear bombs.

X-risk scientists are unlikely to study Earth-threatening asteroids. Instead, they might ask specialists in pandemics or biosecurity to look at the knock-on effects of a strike.

LIKELY DATE: **50 TO 100 MILLION YEARS**
PRIORITY (IN 2017): **LOW**

Worried readers can look to Nasa's Near-Earth Object Program, which lists potential Earth impacts

7. LIFE AS WE KNOW IT PROVES A COMPLEX SIMULATION

In order to calculate some complex risks accurately, X-risk researchers have to factor in the limitations on what they can know for sure. At the most esoteric end of such work lie the possibilities that far from being the most intelligent life forms in the Universe (at least until computers overtake us), we are in fact minor players caught up in something we cannot understand.

This is similar to the "Brain in a vat" experiment used to explain scepticism or solipsism

The simulation hypothesis is the supposition that humans, with all our history and culture, are just an experiment or plaything of a bigger entity, as explored in *The Truman Show*. At the FHI, Bostrom says that this thinking is considered because it "is a constraint on what you might believe about the future and our place in the world".

Similar is the Boltzmann brain concept, named in 2004 after the physicist Ludwig Boltzmann. Essentially, it is the idea that humans are one random coming-together of matter in a multiverse where there are many more things than we will ever know about. Quantum mechanics suggest that the smallest amounts of energy can occasionally generate a molecule of matter. It therefore follows that given infinite time, they could randomly generate a self-aware brain, but it wouldn't necessarily comprehend anything beyond its own experience.

Some proponents use this concept to explain why the Universe seems so incredibly well-ordered. Other philosophers and scientists work hard at proving why Boltzmann brains cannot exist. "Very few people take Boltzmann brains very seriously," Sandberg says, "but they are an annoying issue." They are rarely investigated as existential risks, partly because there's nothing anyone could do about them even if they were true and, as Sandberg adds, "there are only 24 hours in the day, after all."

LIKELY DATE: **UNKNOWABLE**
PRIORITY: **VERY LOW**

8. FOOD SHORTAGES CAUSE MASS STARVATION

The global population is forecast to hit 9.6 billion by 2050. Some observers argue that to avoid mass starvation, we will need to increase food production by 70 per cent in just over 30 years. The challenge is that advances in food-production techniques, which have allowed humans to keep pace with population growth since 1950, largely relied on fossil fuels. In addition, cultivable land is being reduced by factors including topsoil erosion and contamination.

There are also risks associated directly with the nature of the foods we eat. It's widely believed that humans will need to eat less meat and more grains. However, whereas advances in crop development have produced varieties that can grow in inhospitable places, scientists warn that they've also increased vulnerability to disease. Whole tracts of wheat, the world's third-most popular cereal crop, could be wiped out by fungal infections, for example: synthetic viruses can only increase the risk of catastrophe.

Experts have predicted that the impact will begin to be felt through sharp price rises around 2020, with the situation becoming critical in developing countries by the middle of the century.

Typically, food shortages lead to riots and political instability, but surprisingly little work has been done to model the resulting social breakdown than might be imagined. "It is one of CSER's ambitions," says Shahar Avin, a research associate, "to get a holistic picture of these catastrophes that includes technology, media, ecosystems and health shocks."

LIKELY DATE: **2050**
PRIORITY: **HIGH**

9. A TRUE VACUUM SUCKS UP THE UNIVERSE AT THE SPEED OF LIGHT

In the esoteric world of existential risk analysis there is a point at which technically serious, doomsday scenarios can easily begin to merge with sci-fi speculation. Particle-accelerator accidents are a case in point.

This is a complex area. For the past ten years there has been conjecture that the particle collisions in accelerators could trigger a reaction that would change the make-up of all matter and the laws of physics. Recently, some academics have argued that what we previously thought were vacuums actually contained particles, and that the Universe does contain a "true vacuum" of absolute nothingness. The true vacuum, so the argument goes, has the potential to suck in the Universe at the speed of light, in a process called vacuum decay. The reason it doesn't is that it is resting in a meta-stable state – but particle accelerators have the potential to disturb it and thus cause it to suck us all up and wipe out our world. Some physicists disagree, saying that Earth has always coped with cosmic rays that potentially have more power to alter matter than a collider. Earth is still here, they argue, so it must be sufficiently robust.

But at the FHI, that argument doesn't convince. Bostrom's PhD dissertation explored how probability calculations can be skewed by our own perspective. His researchers say that our existence cannot be used to prove the impossibility of this kind of decay, because millions of other Earths could have been wiped out by it in the past.

This led to a paper examining the risk of other scientific papers being wrong. It found that one per cent should be retracted because of calculation and modelling errors. "So even a reassuring paper should only ever make you 99 per cent certain there is no risk," Sandberg says. "One per cent is always unknown."

LIKELY DATE: **TECHNICALLY NOW**
PRIORITY: **VERY LOW**

Millions of other Earths could have been wiped out in the past, leaving no trace. Sorry about that

A concerned biochemist tried to delay experiments at the Large Hadron Collider before it opened by petitioning EU and US courts

10. A TYRANNICAL LEADER UNDERMINES GLOBAL STABILITY

The morning after Donald Trump was elected US president, staff at CSER held a group meeting to discuss whether his election constituted an existential threat. They held a similar meeting following the EU referendum.

Such events can have significant effects on humankind, in particular their implications on our ability to co-ordinate globally to tackle problems such as climate change and to avoid potentially disastrous conflicts. Even more important, however, are the ways in which events like this impact upon how policy decisions will be made and communicated, such as the rise of "post-factualism", as CSER's Weitzdörfer puts it. "With Trump, we are moving away from a world in which scientific evidence counts in debates," he says. "That impedes our ability to deal with any kind of threats. It makes our governance worse and increases risk."

Some political observers in the X-risk community, such as CSER's Simon Beard, argue that the idea that the US as a whole now represents a greater threat to global stability might have an element of overreaction to it, given that Hillary Clinton won the popular vote. There may even be a very slight benefit, at least for the public profile of X-risk as a discipline. "Artificial intelligence draws a lot of attention for us," Weitzdörfer says. "But with the Trump situation it's becoming plausible to more and more people that there are other serious risks we need to think about."

LIKELY DATE: **NOW**
PRIORITY: **MEDIUM**

Richard Benson is a freelance journalist. He wrote about TheLADbible in issue 09.16

MARCUS KRAUSE WAS PREPARING FOR THE WORST AFTER HIS LUNG CANCER KEPT GROWING. THEN HE TOOK A NEW KIND OF BLOOD TEST. THE TEST, BY STARTUP GUARDANT HEALTH, MONITORS A TUMOUR'S OWN DNA. AND THAT COULD OFFER A WHOLE NEW APPROACH TO SAVING LIVES

BLOOD

BY **JOÃO MEDEIROS**

PHOTOGRAPHY: **BENEDICT EVANS**

BLOOD PHOTOGRAPHY: **PAUL ZAK**

IN LATE AUGUST 2014, MARCUS KRAUSE, A 53-YEAR-OLD PHOTOGRAPHER FROM ATLANTA, RECEIVED A PHONE CALL FROM HIS ONCOLOGIST. KRAUSE HAD BEEN WAITING FOR THIS CALL FOR MORE THAN TWO WEEKS. HE WAS TO BE INFORMED WHETHER HIS LUNG CANCER WAS TREATABLE OR NOT.

KRAUSE'S CONDITION HAD BEEN RELATIVELY asymptomatic. Looking back, however, there had been some signs that he didn't pick up. For instance, he had been oblivious to a persistent dry cough he had developed. He had also been feeling slightly out of shape – he regularly cycled long distances but lately it would take him longer to recover. Until one day, in mid July, when he was forced to stop abruptly during a bike sprint to the top of a hill. He felt out of breath and had to sit down for several minutes to recover. In the next few days, he developed flu-like symptoms and went to see his doctor. An X-ray revealed that his right lung was being compressed by pleural fluid. The following morning, the doctor extracted a few litres of liquid. "They couldn't remove all of it at once because my body had grown accustomed to having that fluid in there," Krause says. The doctor installed a catheter on his ribs and instructed his wife, Amy, on how to drain the rest of the fluid at home. A couple of days later, Krause underwent a PET scan. It revealed the culprit for the pleural effusion: a 2.8cm tumour lodged on his bronchial tube. Given the location of the tumour, performing a tissue biopsy would have been complicated, so the oncologist collected tumour cells from the pleural fluid. The diagnosis: Krause had stage-four lung adenocarcinoma. In other words, lung cancer.

The question now was whether his cancer had a gene mutation that could be targeted by existing drugs or not. Targeted cancer therapies interfere with the genetic mutation that causes the tumour to grow. They outperform more traditional treatments such as chemotherapy and are generally effective if you have the right drug for the specific cancer mutation. Of the 150 genetic mutations known to cause cancer, 70 are currently treatable by targeted drug therapies.

Krause had done his homework and thought it was likely that for someone in his fifties and healthy, who had never smoked, he would have a targetable mutation. When he finally got a call from his oncologist, however, he received some bad news. There was nothing they could target.

Initially, Krause responded well to chemotherapy. "It was a new treatment that hadn't yet been approved, but it was being fast-tracked," he says. "My oncologist really wanted me to do that and made an appeal to the insurance company on my behalf, so they granted me an exception." After 12 weeks of chemotherapy, his first CAT scan showed a 70 per cent tumour reduction. His second scan in December 2015, however, showed that it had grown to five centimetres. Krause's wife cried when she heard the news. Krause, on the other hand, felt relieved. "I didn't want more chemotherapy," he says. "It just makes you so sick and I knew that it wasn't going to cure me. So the question was: do I just want to feel like hell and then die, or do I want to maybe feel OK and then die?"

At this point, Krause's doctor referred him to an oncologist at the Sarah Cannon Research Institute in Nashville, in the hope that he could at least enrol him in upcoming clinical trials. The Nashville oncologist, however, wasn't convinced about Krause's biopsy results and asked him if he was willing to undergo another test. It wouldn't be a tissue biopsy, but a blood test instead. The test was new but early studies had shown promising results. Unlike a tissue biopsy, it wasn't invasive. All they needed was two vials of blood. Krause had nothing to lose. He agreed.

In the meantime, he was put on another course of chemotherapy. He was busy at work, his eldest daughter's wedding was coming up and he needed something to keep him going. "The wedding was emotional," Krause says. "Everybody knew things were not looking good at that point." The new chemotherapy soon also proved ineffective. By then, Krause had forgotten about the blood biopsy test. "When I called my oncologist to ask 'What now?', he said, 'You remember that blood test we did?'" The test had revealed a mutation, an epidermal growth factor receptor (EGFR), that the first biopsy had missed. Krause had reason to hope again.

RIGHT: MARCUS KRAUSE IN THE GARDEN OF HIS ATLANTA HOME, 2016

PREVIOUS SPREAD: SET DESIGN: VICKY LEES

ONE DAY IN 2013, HELMY ELTOUKHY, A 34-YEAR-OLD electrical engineer from California, flew to Spain to meet a Swiss researcher named Maurice Stroun. Eltoukhy had just started his second company, Guardant Health, with former PhD colleague AmirAli Talasaz, but he didn't have a product yet. Instead, he had a vision – to invent a new test that would replace tissue biopsies with a blood test. And Stroun, one of the scientists who had discovered the existence of cancer DNA in blood, could help him.

Eltoukhy had studied at Stanford University, where he was involved in projects that used semiconductors to make cheaper and faster DNA sequencers. His group, headed by Iranian molecular biologist Mostafa Ronaghi, had received $10 million (£7.7m) in grants. With that money, Eltoukhy and Ronaghi spun out a company, Avantome, in 2007. A year later, they sold Avantome to Illumina, the world's leading manufacturer of sequencing machines. Eltoukhy and Ronaghi joined the company, where they supervised half of the projects at its R&D department.

In 2011, Eltoukhy felt ill. The list of symptoms was unusual: brain fog, arthritis, stomach pains and exhaustion. He went to 12 specialists, undergoing multiple blood tests, a colonoscopy, an endoscopy and a CT scan. No one could tell him what was wrong with him. "I was freaking out," he admits.

One evening, his wife organised a make-your-own-pizza party at home for their friends. Eltoukhy binged on pizza and bagels and, later that night, a rash broke out, covering his entire body. After seeing him, his doctor suggested he might want to try cutting gluten out of his diet. Four weeks later, his health was restored.

The appointments with various physicians during those six months made Eltoukhy reflect that they had poor technological tools to help in diagnosing and treating disease. "I always considered physicians to be the heroes on the front line," Eltoukhy says. "They are on call, they are helping people at their time of most desperate need and yet they don't have the tools to ask and answer the right questions."

Eltoukhy decided to quit his job and do something about it. "It was all about reducing the cost of sequencing," he says. "Can we get to the $500 genome? The $250 genome? I just felt we were killing ourselves with advanced physics while there was a lot that we could be doing closer to patient care. I felt that if I wasn't a part of this revolution I would always regret it." He decided instead to focus on the disease that had taken his grandmother at 40, and still one of the biggest killers in the world. "Cancer is a disease of the genome," adds Eltoukhy. "I figured that's the one area where our knowledge of advanced genomic sequencing would make a big difference."

From his perspective as an engineer, how oncologists diagnose and treat cancer constitutes what Eltoukhy considers a faulty feedback loop. "When you think about diseases that we have been able to combat effectively, whether infectious diseases, HIV or even blood cancers such as leukaemia and lymphoma, which have fairly high survival rates now, it's because we have access to information about the disease through a simple blood test," Eltoukhy says. "We can access and sample the disease continuously. Unfortunately, in solid tumour cancers, it takes three to nine months to figure out if a drug works. The feedback loop is enormously slow."

Furthermore, this slow feedback loop doesn't even track the underlying genomics of the disease. A cancer genome evolves all the time – the early mutation that drives the initial stages of the cancer will not be the same a few years down the line. Its genome can change, adapt to treatments and multiply into various mutations that evolve independently from the original one. "Cancer is the one disease where you will do an initial tissue biopsy and use that information for

Below:
Blood samples in Guardant's Redwood lab.
Far left: The company's co-founder AmirAli Talasaz

the rest of that patient's life," Eltoukhy says. "By then the cancer has grown and evolved, acquiring different mutations, and the physician may have no idea. It could be five or ten years, and we're still acting on the original diagnostic. Unless you keep testing, you are not going to be able to effectively correct the treatment and change the drugs every time it's required. We have to manage the disease dynamically and adaptively."

He soon found out that a blood test could provide one possible way to measure cancer mutations without the need for an invasive tissue biopsy. It would allow doctors to test patients more regularly to track the cancer's evolution. This would avoid the need for several painful and invasive tissue biopsies that were detrimental to the health of the patient. It could also be available as part of an annual checkup, something that would work equally for early diagnosis and the sickest patients. When he searched academic literature for articles on cancer DNA in the circulatory system, all the references pointed towards one name: Maurice Stroun.

Stroun wasn't a cancer expert. He was a plant physiologist at the University of Geneva. In the 60s, he had studied tumours caused by bacteria in plants and found genetic material of the bacteria in the sap of tomato plants. This led him to study animal species and, in 1972, he found bacterial DNA in the circulatory system of frogs. This showed Stroun that it was possible to detect genetic material from a foreign body such as a bacterial tumour in an organism's circulatory system. When he came across a study that showed that cancer patients possessed higher quantities of DNA in their blood serum than non-patients, Stroun wondered whether that extra DNA was from the cancer tumour itself. In 1994, his group became one of the first to successfully detect DNA from cancer tumours, so called cell-free DNA, in the cardiovascular system of cancer patients.

"The theory was that, as a cancerous tumour grows and its cells multiply, it begins outgrowing its blood supply," Eltoukhy says. "Even in early-stage cancers, its cellular growth rate is only narrowly higher than its death rate. As

cells die, they shed their contents into the blood stream, including its DNA."

When Eltoukhy met Stroun, they immediately hit it off. Guardant Health subsequently acquired several of Stroun's patents and he became the company's founding adviser. In 2014, Guardant launched its first blood biopsy test. "Stroun's a guy who didn't get a lot of credit and respect from the cancer community, because of his background as a plant physiologist," Eltoukhy says. "Of course, a lot of the sequencing technology had to be developed to make comprehensive liquid biopsies happen. I think people are now looking back and realising he was right about a lot of things."

IT'S JULY 15, 2016, AND WIRED IS attending a meeting at Guardant Health's offices in Redwood, California. Some challenging case studies are discussed. Richard Lanman, Guardant's chief medical officer, leads the group. "Every week, new employees join the company," Lanman says. "Reviewing cases is a way to introduce them to our technology."

Lanman is in his fifties and has been at Guardant since September 2014. One of the first studies he conducted was an analysis of the costs of biopsies which was recently published in the *Clinical Lung Cancer* journal. The study reported that a lung biopsy cost, on average, $14,634. This included the cost of subsequent complications from the surgery, experienced by one in five patients who undertake the procedure. Guardant Health's test costs $5,800.

"Today's physicians want more tissue, so the needles are getting bigger, which only increases the complication rate," Lanman says. "If you go to a top hospital you should have no problem getting a comprehensive sequencing of your tumour. But what about patients who don't have such access?" For a blood test such as Guardant's all you need is a nurse, FedEx and $5,800. "We're democratising access to biopsies."

A few weeks before WIRED's visit, at the annual American Society of Clinical Oncology meeting, Helmy Eltoukhy had announced the results of a study involving 15,000 cancer patients. The study demonstrated that Guardant's blood-test results agreed 99 per cent of the time with the results of a standard invasive tissue biopsy. This concordance level dropped to 67 per cent when a Guardant test was compared to tissue biopsies taken more than six months earlier. "That's what you would expect," Eltoukhy tells WIRED. "It tells you that the original mutation has evolved and the original biopsy result no longer applies."

This secondary wave of mutations is what Lanman calls "the landscape of resistance". "These mutations are why treatments almost always fail," he says. The first genetic mutation that leads to cancer might be caused by a variety of factors: environmental, chemical, gamma radiations from space, viruses or inherited defects that impair our ability to repair DNA. "When enough of those mutations happen in the right way it causes cells to go out of control," he says. This initial mutation will continue to grow unimpeded until it's resisted by medical treatment. "Until then, cancer cells had no reason to mutate," Lanman continues. "Medical treatment forces the cancer to evolve, to get around the treatment."

It's this landscape of resistance that Guardant is starting to map. The more clinicians know about the type of mutations that arise after the first mutation, the better these mutations can be targeted throughout a patient's lifetime. "Because our blood test is used most often when the first line of treatment has failed, we have the largest database of resistance mutations," Lanman says.

His hope is not for a cure, but for management of the disease much as we manage HIV. "People have talked about cures since 1980," Lanman explains. "I don't think that will happen any time soon. I do, however, think we're on the verge of managing cancer."

After his introduction at the meeting, Lanman presents a few case studies. The first was a patient – male, 55 years old, based in Tel Aviv – with metastatic lung cancer. They found an EGFR L858R mutation for which there is a match therapy, a drug called erlotinib. "He did well for a while, but then the cancer evolved," Lanman says. "When they biopsied the patient again, 13 months later, they found eight new mutations." None had a treatment at the time. In July 2014, the patient took a blood test with Guardant. The test found another mutation, T790M, in the EGFR gene. "It was driving all the resistance to the treatments," Lanman explains. "We tried to get into a clinical trial for a new drug for that mutation, but the company didn't enrol him." Guardant had just launched and the pharmaceutical company was unwilling to take a risk on a new diagnostic tool. A few months later, the patient's tumour metastasised, invading the liver. In September 2014, a standard liver tissue biopsy detected the EGFR-T790M mutation, confirming Guardant's result. They put him on a clinical trial and, by January 2015, the tumour had shrunk by 40 per cent. "He did well until they did another lung tissue biopsy. They stuck a needle in him, caused a lung collapse, and he died." The biopsy – not the cancer – killed the patient.

Another case study presented by Lanman was a 60-year-old male patient with metastatic colorectal cancer. The patient had received treatment, but it was stopped when he developed complications. "He was frail and ready for palliative care," Lanman says. The tissue biopsy, however, hadn't detected an ERBB2 gene amplification, an alteration in the number of copies of the gene. This is one of four types of cancer mutations. The basic one is just a letter change in the four-letter genomic code. The second type is a fusion of two genes, and a third happens when a letter is inserted or deleted from the code. The fourth type is an alteration on the number of copies for each gene, of which the ERBB2 amplification is one example. "We all have two copies of every gene in our genome," Lanman says. "In some cancers, you can have eight, 15 or 100 copies. These can be hard to detect."

Guardant's is the only test that can detect the four types of mutations. The patient was put on trastuzumab, an extremely efficient drug. "The tumour dissolved," Lanman says. "The results can be dramatic even when you are on death's door."

A final case study: a 58-year-old female with lung cancer and bone metastasis. "She received chemo and three biopsies," Lanman explains. "But they couldn't get enough tissue to sequence." Her oncologist ordered a blood test; the results showed the presence of two molecules with a EML4-ALK fusion mutation in ten millilitres of blood. "It was a low amount," Lanman says. "But if it's there, it's a detection."

Guardant's blood biopsies have a specificity of 99.999999 per cent –

FOR A BLOOD TEST SUCH AS GUARDANT'S, ALL YOU NEED IS A NURSE, FEDEX AND $5,800: 'WE'RE DEMOCRATISING ACCESS TO BIOPSIES'

which means that the test reports no false positives – thanks to a method it developed called digital sequencing. "We barcode each of the two complementary strands of DNA and make sure they match up. Most sequencing methods do not include this step, and can get false positives. There's nothing like this in diagnostics," Lanman says.

The patient was treated with a drug called crizotinib and recovered. "She went from no options to a great response to treatment because of a blood test."

Below: Guardant Health co-founder Helmy Eltoukhy

After his Guardant test in 2015, Marcus Krause begun a treatment with erlotinib. Before, he had to take narcotics to alleviate the pain. Within two days of starting on the drug, he no longer felt pain. After eight weeks, he took a CAT scan. His previous scan had shown a five-centimetre tumour, with nodules invading his chest cavity and a cancerous lymph node on his liver. The new scan showed that the lymph node had cleared, the nodules were gone and the tumour had shrunk to one centimetre.

In May 2016, at the invitation of Helmy Eltoukhy, Krause visited Guardant's offices in Redwood to meet the team and share his story. That day Guardant was launching a new initiative called Project Lunar in collaboration with the University of California, San Francisco, South Korea's Samsung Medical Centre, the University of Pennsylvania and the University of Colorado. The study involves, at an early stage, hundreds of pre-symptomatic, high-risk individuals for breast, ovarian, colorectal, pancreatic and lung cancer. "These are patients who, like Angelina Jolie, have a BRCA mutation for breast cancer," Eltoukhy says. "Most of these women have to make a choice about removing their breasts and ovaries. What the study will do with those having surgery is to take a blood sample and compare it with the tissue that has been removed, where sometimes you find early stage-cancer lesions." With Lunar, Guardant is focusing not on the landscape of resistance, but on the original mutation. If successful, the study will be a step in the direction of Eltoukhy's original vision: a tool for early detection of cancer. "They will be able to use our test for active surveillance rather than make a big decision to surgically remove their organs," Eltoukhy says.

That afternoon, Krause took part in a panel discussion. He recounted his story to an audience of Guardant scientists and lab technicians: how his mutation had been missed with a standard tissue biopsy; the bad shape he was in when the chemotherapy stopped having an effect; and how the blood test had saved him. He knows that erlotinib won't last forever. At some point, the cancer will mutate and become resistant to the drug. There's a 60 per cent chance that the new mutation will be T790M, in which case the prescribed treatment will be a drug called osimertinib. He can live like this, he says. Managing the disease. He feels like he's not even sick.

"My story made such a big impression," Krause remembers. "The scientists spend most of their time in the lab and to hear such an incredible turnaround story from a person standing in front of them was a big deal." At the end, he told the audience: "When things get rough again, I'm just going to remember standing here looking at each of you. That's going to inspire me to keep going."

João Medeiros is WIRED*'s science editor. He wrote about Team Sky in 07.16*

Facebook and Twitter wield huge influence over how people understand the world around them. This is the year we confront that

THE SOCIAL MEDIUM IS THE MESSAGE

Social networks have been exposed. No one can pretend that they are simply neutral platforms – mere tubes and pathways, like phone lines, that allow us to share snippets of our lives. That fiction was laid bare on November 8, 2016.

Over the next year mainstream culture will grapple, for real, with the civic and political effects of our lives online. Many intellectuals, with eyebrows cocked, have warned that this reckoning was coming. But it took the US election – and the ascent of Donald Trump, the insult-hurling, falsehood-circulating tweeter-in-chief – to shine a blinding arc light on technology's role on the political stage.

We are thus heading into a very McLuhanesque year. Marshall McLuhan – the Patron Saint of WIRED – made his name in the 60s, studying how pivotal technologies produced widespread, non-obvious changes. The Gutenberg press, he argued, created a spirit of "detachment" that propelled science while giving a new sense of agency to individuals. Electricity had a "tactile" effect, keeping us in constant contact with the world via the telegraph, telephone and TV. The photocopier imposed a "reign of terror" on publishers by letting everyday folks copy documents.

People assume McLuhan was always a cheerleader for these shifts. But his thinking could vibrate with anxiety at the coming impact of electronic media. He suspected we could have too much contact with each other – that we'd become fearful and angry by incessant exposure to the world. He might have looked at Trump's rise on Twitter and nodded in recognition; a young McLuhan had watched European fascists in the 40s inject hypernationalism into supporters' souls, via the radio.

When Trump won last year to widespread shock, liberal critics attacked the major social networks for enabling several unsettling trends. Platforms such as Facebook and Twitter were viral hotbeds for conspiracy theories and disinformation. Memes that reared to life on image boards and fringe political sites – jittery with misogyny and white nationalism and hatred of Hillary Clinton – made the leap to the mainstream on social networks. Dangerous falsehoods, such as the idea that Clinton ran a child-trafficking ring out of a pizzeria, spread widely; indeed, on Facebook, the top 20 fabricated stories netted more engagement than real stories from news sources that actually did factual reporting, as BuzzFeed found. (This isn't a problem only in

By

Clive Thompson

Illustration:

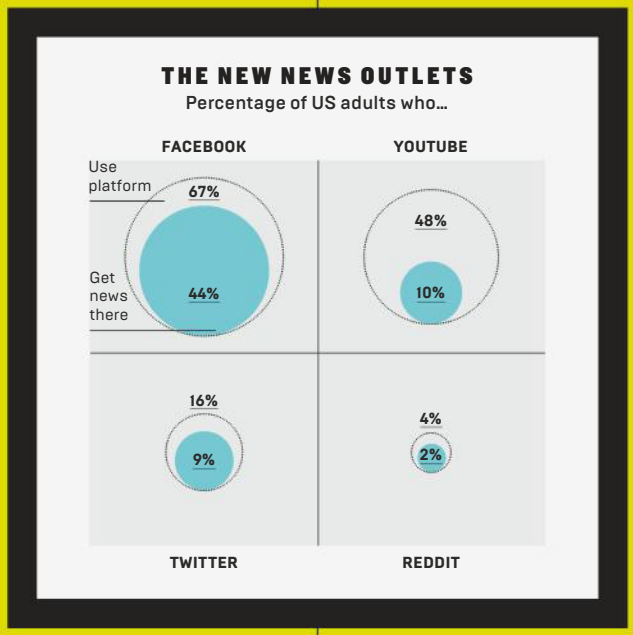
Eddie Guy

the US: anti-Muslim conspiracy stories are avidly circulated on Facebook in Myanmar, and Germans trade Facebook posts claiming Angela Merkel is Adolf Hitler's daughter.) The same was true on Twitter, which became a tool for small numbers of people to propagate abuse and hate speech.

Meanwhile, the "filter-bubble" effect, which writer Eli Pariser had pinpointed years before, arrived in full force. As my friend Zeynep Tufekci, a sociologist at the University of North Carolina and author of an upcoming book about political organising in the digital age, says, "I'm Facebook friends with some people who support Trump, but I don't recall seeing their Facebook updates – it appears the algorithms assumed I wouldn't be interested."

We can't indict social media alone, or even primarily, for the rise of disinformation and politically abusive behaviour. Traditional media – cable TV, radio, newspapers – recklessly amplified nonsense this political season (and were played shamelessly by Russia's email hacking). They need their own reckoning. But social networks increasingly influence how people learn about the world. According to the Pew Research Center, about 44 per cent of Americans cite Facebook as a news source. It is a crucial part of "where we put the cursor of our attention all day long," says Tim Wu, author of *The Attention Merchants* and *The Master Switch*.

It seems the question that's lingering in the air is: how should social networks grapple with their civic impact? As we will discover, these issues will be devilishly hard to resolve.



The optimistic view is that there's good precedent for fighting crap online. Back in the aughts, internet giants waged a war against spam and content farms. To cut down on spam entreaties from Nigerian princes and the like, email providers used machine learning to detect spam-like content; they also created shared blacklists. To quash content farms – low-quality insta-websites designed to game its top slot – Google created an ambitious ranking scheme called Panda. This down-ranked sites that employed tricks such as keyword stuffing (putting lots of invisible, unrelated phrases on a page). Remarkably, it worked: content farms vanished and bulk spam is now mostly a marginal problem.

Social networks could use similar strategies to solve their current civic dilemmas. Consider fake news, an area where, as scholars have shown, algorithmic analysis could help identify crap. Software created by Kate Starbird, a professor of design and engineering, was able to distinguish with 88 per cent accuracy whether a tweet was spreading a rumour or correcting it when analysing chatter about a 2014 hostage crisis in Sydney. And Filippo Menczer, a professor of informatics at Indiana University, has found that Twitter accounts posting political fakery have a heat signature: they tweet relentlessly and rarely reply to others.

Social networks sit atop piles of data that can help identify bogus memes – and they can rely on their users' eagerness to help too. Sure enough, Facebook has already begun to develop tools along these lines. In December 2016, it unveiled a system that makes it easier for anyone to flag a post if it seems like deliberate misinformation. If a link that purports to be a news story is flagged by many users, it's sent to a human Facebook team. The team adds it to a queue, where external fact-checking firms, including Snopes and Politifact, can check if they think the story is suspect. If they do, Facebook warns that it is "disputed by third-party fact checkers" and offers links to rebuttals by Snopes or others. If a user tries to share the story later, Facebook warns them that it's disputed. The goal isn't to catch all falsehoods; the system targets the most blatant posts.

There are plenty of other tweaks platforms could make. Craig Silverman, a BuzzFeed editor who has closely studied fake news, argues that Facebook and Twitter ought to make it easier to see the provenance of a link; right now, those from carefully reported sources such as *The Wall Street Journal* look the same as ones from conspiracy sites. The platforms could instead emphasise logos and names so a user might realise, Silverman says, "Wait a minute, this domain name is hillaryclintonstartedaids.com."

Now let's look at the filter-bubble phenomenon. Social media platforms could design algorithms that would expose us to people, ideas and posts that aren't in such lockstep with our views. Then, when a platform such as Facebook suggests related content, "You could use these mechanisms to surface ideas that are ideologically challenging," Pariser explains. Or as Tufekci argues: "Show more cross-cutting stuff! I'm not saying drown users in it. But the default shouldn't be: 'We're just gonna feed you candy.'"

INFOGRAPHIC SOURCE: PEW RESEARCH CENTER

Let your imagination go wild and you can concoct even more aggressive, more ambitious reforms. Imagine if you got rid of all the markers of virality: no counts of likes on Facebook, retweets on Twitter, or upvotes on Reddit! Artist Ben Grosser created a playful browser plug-in called the Facebook Demetricator that does precisely this. It's fascinating to try: suddenly, social media stops being a popularity contest. You start assessing posts based on what they say instead of because they racked up 23,000 reposts.

Some scholars argue Facebook should hire human teams to more comprehensively review trending stories, deleting ones built on lies. In fact, Facebook did just that last year until a conservative outcry ended the practice.

The biggest impediment to all this change, though, is economic. Traditional media organisations publish and broadcast nonsense because it attracts eyeballs for ads. New media have inherited this problem in spades: they know – in vivid, quantitative detail – just how much their users prefer to see posts they agree with ideologically, seductive falsehoods included. Spam got on people's nerves, so companies were eager to stamp it out; on some level, social platforms' attempts to fight fake news and confirmation bias will come into conflict with their users' appetite for them.

Nonetheless, public pressure did, in fact, prod Facebook to action after the US election. Imagine if greater pressure impelled platforms to take an even stronger stand against falsehoods and filter bubbles. Would we like the result?

It's unclear. Waging war on disinformation isn't easy, because not everyone agrees on what disinformation is. It's unambiguous that "the Pope endorses Donald Trump" isn't true. But how about "Hillary Clinton lied about having pneumonia, so she's a lying snake"? The most effective disinformation usually begins with a fact then amplifies, distorts, or elides; ban the distortion and you risk looking like you're banning the nugget of truth too. Online interactions are conversation, and conversation has always been filled with bluster and canards. "The idea that only truth should be allowed on social networks is antithetical to how people socially interact," says Karen North, a professor of digital social media at the University of Southern California.

Or consider this example raised by New York University media theorist Clay Shirky: in 2016, supporters of the Dakota Pipeline protests were encouraged to "check in" on Facebook at that location to confuse police. Those false check-ins "are fake news", Shirky notes. Any policy aimed at enforcing truth on Facebook could easily be used to quash that activity.

"Look, fake news is a real problem," he says. "But do liberals really want to hand the decisions over to a single large corporation?" Asking the platforms to be granular arbiters of truth would endow them with even more power. Whatever one can say about Donald Trump, he understands – and masterfully plays – the media, old and new. He uses Twitter to perform an end run around journalism, to utter falsehoods that are repeated by his followers and circulated further by mainstream news. When he attacks someone in a tweet, his supporters harass the target. Like other merchants of disinformation online, Trump exhales such a cloud of half-baked assertions that it leaves people mistrustful of everything. If you can do that, hey, what does it matter if social networks slap a "Disputed" label on the post you wrote? As Jon Favreau, one of Barack Obama's former speechwriters, puts it: "Donald Trump doesn't care if we think he's telling the truth – he just wants his supporters to doubt that anyone's telling the truth."

And yet Trump has millions of eager followers. This is what gives pause to Jay Rosen, a professor of journalism at New York University. "You have to think about the demand side," he says. It's not enough to ask why people spread political disinformation, he adds. You also have to ask, "Why do people want to consume this stuff so much?"

THE MOST EFFECTIVE DISINFORMATION HIDES AMID ACTUAL FACTS

Ponder that and you realise, there are limits to what technological fixes can achieve in civic life. Though social networks amplify American partisanship and distrust of institutions, those problems have been rising for years. There are plenty of drivers: say, 20 years of right-wing messaging about how mainstream institutions – media, universities, scientists – cannot be trusted (a "retreat from empiricism", says Rosen). As danah boyd, head of the Data and Society think tank, notes, we have lost many of the mechanisms that once used to bridge the various cultural gaps between people from many different walks of life, including widespread military service, affordable colleges and mixed neighbourhoods.

The old order was flawed and elitist. It also locked out too many voices; it produced seeming consensus by preventing many from being heard. We are fumbling around for mechanisms that can replace and also improve upon that order, Pariser says. "It reminds me of how the secular world hasn't found a replacement for some of the uses and tools that religions served. And the new media world hasn't found a replacement for the ways that consensus was manufactured in the old world," he adds. This is the year that we need to begin rebuilding those connections – on our platforms and in ourselves.

Clive Thompson is a contributing editor to WIRED US *and the author of* Smarter Than You Think

A local farmer cycles from Shaoxing to Zan Gong village, where Qiu Sai Zhen runs a Ule-connected general store

By David Rowan
Photography:
Stefen Chow

GLOBAL VILLAGE

How rural Chinese stores became the world's most connected retailers – thanks to a billionaire investor, a data-crunching genius... and thousands of local postmen

LOU WENER WORKS DAMN HARD. "FIVE AM to 10pm, seven days a week, including national holidays," the 45-year-old shopkeeper says distractedly behind the cluttered counter of her Xiabao village general store in Zhejiang province, a couple of hours' drive west of Hangzhou city. In fact, she explains as she checks a customer's egg delivery for freshness, she and her husband don't close the shop, not even for Chinese New Year. "Of course we stay open," she says, smiling tolerantly as an elderly customer holding detergent looks on bemused at a western journalist's presence. "That's a very busy day for us."

Lou grew up here in Xiabao, a village of around 1,000 people set among paddy fields and hectares of longjing tea, its outskirts marked by roadside stalls selling locally grown melons and apples. She's run the store for 21 years and lives upstairs with her farmer husband, his father, and their 21-year-old son. "When we first opened, business was good, as people didn't often go to town to buy things," she says. "But in recent years it's got much harder. It's [e-commerce website] Taobao. People started learning how to buy online around 2014; their kids taught them. Then the smartphone arrived. They just stopped buying daily goods. We felt the pressure: it was only old people coming in to the store. If we didn't change, we would be eliminated by the internet." Then, in July 2015, the local postman offered to turn Lou's simple store into a

TYPOGRAPHY: SU LIQUN DAVID

Below: Lou Wener serves customers at the store she has run for 21 years in Xiabao village, Zhejiang province

data-enabled, real-time-responsive, globally connected e-commerce hub of its own. With help from the postman, she plugged an electronic point-of-sale laser scanner, a till-receipt printer and a digital weighing scale into a new Asus laptop that sits between a router, a cash register and a landline towered over by western and Chinese cigarette packs. Now whenever a customer pays for a Funkid Grapefruit Juice or a Hazelive Soap, their purchase is tracked instantly on a central database. It is linked to both the shopkeeper and that particular customer, whose membership card is then credited with loyalty points that can be redeemed for a purchase of blueberry juice or rice wine.

A wall-mounted 42" Sanyo TV displays the *WeChat* group that Lou maintains for the store: a special offer on trainers if ten villagers will commit; prices for latex pillows and organic duck eggs that the postman can deliver to the store by next morning. *WeChat* lets her tell customers that their order has arrived. On hot days she may deliver locally. There is a China Post logo on the shop awning above a red lantern, which sits alongside a red logo containing the web address "ule.com".

These are clues to the ambitious retail experiment that has embraced this village store. On the floor sit two half-opened boxes of yams that the postman brought today for Lou's customers from a neighbouring province. They lie next to a large box of packed tea brought to the store by a local farmer to be sold on Lou's store website and collected for delivery by the same postman on his way back into town. These are what Lou calls her "virtual SKUs", or stock-keeping units, that give her customers access to thousands more lines than can fit in her cluttered physical store: cotton shirts, denim jeans, dry beef jerky, flowerpots, adhesive tape, chopsticks, dragonfruit, socks, cooking oil, doormats... all brought reliably by next-day China Post delivery.

In one month in 2015, Lou says, her website sold 800 pairs of shoes to this 1,000-person village. And that she credits entirely to her membership of Ule – the fast-growing commerce platform created by the postal service and a Hong Kong multibillionaire, which aims to transform a million village stores into the world's biggest real-time searchable retail database.

So far today, according to Ule's mobile app, Lou's taken 40 orders, earning 1,719RMB (£200) in revenue and 116RMB (£13) in profit. Yesterday, 71 orders brought in 3,295RMB and 180RMB profit. Ule's point-of-sale device lets customers pay utility bills in the store and manage their Postal Bank accounts, further boosting Lou's income. A quarter of her turnover is now online, with a growing trade in outbound sales of local farmers' shredded bamboo, fungus and dried vegetables. There are so many products that she's had to rent the warehouse opposite to store them.

Because Lou's trading data is transparent within Ule's network, the Postal Bank has offered her a 90,000RMB revolving credit line at a preferable interest rate. The offline, non-Ule store next door, meanwhile, "isn't doing well", according to Lou. She says her revenue has doubled since she joined Ule. "I was going to close down as business was so hard," she says. "Young people weren't coming, but now with mobile sharing they know there's a promotion on milk, and we can sell 80 boxes of milk in a day. Or they tell me what they want. I search on Ule for it and it comes in the next day. It may be a bit more expensive than Taobao, but you don't have to worry about fake products. I take care of everything. It's a long, hard day but I feel fulfilled. With the mobile, we're very busy. Before it was so boring that I wanted to cry."

SAMSON YEUNG WON'T RELENT IN connecting China's village stores until he's reached saturation. "A million stores would be a very good number to dominate the market," he says as we drive along the winding hills that lead to the last remaining store in the village of Yaocun. It's 20km past the nearest small town. "China has 700,000 villages, and we are planning to have one Ule store per village, plus 20 or 30 per city. Then we'll cover all China's rural areas and the best parts of the city," he adds.

As Ule's chief operating officer, Yeung is moving fast to build the world's most ambitious real-time retail-data network. In August, when WIRED tours the villages of Zhejiang province, there are 250,000 stores on the Ule system; by late December, that will rise to 330,000. And because each store owner scans every

Above: Warehouse facilities in Yuhang district, from where 400 local Ule clients are served

product variation into the system, to identify everything from Coke to local cabbage, Ule now tracks more than three million individual SKUs. "Point-of-sale is just the beginning," Yeung explains. "Being on the network makes each store a virtual Walmart: they can sell what they like, even if it's not in the shop, to turn themselves into internet businesses. Plus we're capturing every transaction that's made in the store, to help the shop-owner. We know who they are selling to, at what time of day and in what weather. We work with the owners to decide where to shelve products for maximum impact."

The Yaocun store is open even longer hours than Lou Wener's: from 6am to midnight, 365 days a year. This is a village of just 150 households, where flowers and wood have brought relative wealth: a 60" TV is visible through an open door in a house in the small market square. "There used to be three stores in this village, but the other two have closed," explains shop owner Han Guo Min, 47, who lives upstairs with his wife, mother and 21-year-old son, who is also their delivery driver. After 20 years here, he joined Ule on May 20, 2015. "It's increased the wealth of the village and given us better-quality SKUs,"

Clockwise from above: Qiu Sai Zhen behind the counter of her Ule store in Zan Gong village; a rural worker harvests crops in Shaoxing, a prefecture-level city; Han Guo Min and wife Qian Mei Ya, who own a Ule store in Yuhang district

Han says. "Ule has meant a 25 per cent growth in revenue, with utilities payment and China Post insurance sales bringing more people into the store. The inventory is automated. Before, I had to memorise prices: if I wasn't in the store, we couldn't sell something."

On an Android phone, Yeung scans the store's daily stats. It's 4pm and Han has taken 22 orders worth 1,500RMB, resulting in 152RMB profit. His seven online orders – including rice wine, cups and a pillow – amount to 436RMB. Store data is updated every five minutes.

That level of near-real-time data from stores across China opens doors that western consumer-insight businesses can only dream of. By recording millions of daily purchases and linking them to individual customers via loyalty cards or phone payments, Ule is building an unprecedented view of Chinese consumer purchases. Let's say you're a beer firm wanting to optimise distribution when demand rises on an unusually hot April day. Ule knows where to send your trucks. Or imagine you're Chanel and you want to know which 44- to 48-year-old women, in villages a few hours from the nearest city, have today bought a Dior product. Ule's data can potentially identify them, perhaps allowing you to send a Chanel discount voucher to their phone.

That's a rich feature set that makes Tesco's Clubcard look quaintly Victorian.

"WHAT WOULD YOU DO IF YOU HAD ALL the retail data in the world?" Kerry Liu, founder of a Toronto analytics company called Rubikloud, is sitting across a Hangzhou conference table explaining how he's turning village-store data into power. "First, there's retail optimisation – you can change how large mass retailers connect with customers and influence them. Retailers need to build relationships with customers in the same way Netflix, Amazon Prime or Facebook treat their customer base, constantly tuning their parameters. Facebook wouldn't say, 'You clicked on an update from your cousin, so now we will show you your cousin every time you log in.'

"Second, you can influence brand and product development – we did a pilot for a big pharmacy chain – and can influence consumer spending, say, to encourage healthier foods.

And third, you can shape new product launches. A razor company wanted to launch a new product without cannibalising sales, so we found the 25,000 most likely customers from the retailer's database, scraped online price data, used reinforcement learning. The result was a 42 per cent rise in product spend."

Rubikloud launched in April 2013 with a mission "to index and predict the world's retail behaviour while turning data into revenue". So far its machine-learning PhDs and data scientists have processed $250 billion (£195bn) in transactional data, which adds up to 500TB. Its first product, largely for the north American market, took point-of-sale data, inventory data, promotional data, customer loyalty data and more to help retailers predict the behaviour of individual customers at scale. And then Liu, 31, met Solina Chau of Horizons Ventures, the Hong Kong-based fund which manages the tech investments of Li Ka-shing, one of Asia's wealthiest men. "After five minutes of our demo, Solina said she wanted to know how we sucked data out. She asked if we'd settle for being acquired by a big company – or whether we wanted to build a proper platform on top of that first framework." Horizons Ventures quickly led a seed investment round. But Chau had bigger plans for Rubikloud. Li's internet and media company, TOM Group, embarked on a huge joint venture in 2010 with state-owned China Post, which has a million workers, to digitise commerce across the nation. They named it "Ule", translated roughly as "Happy post".

Today, Ule and TOM Group each own 7.5 per cent of Rubikloud, now at 55 people. They have also both invested in a Hong Kong-based finance-tech startup called WeLab, which uses mobile and offline analytics to determine whether a shopkeeper or a customer is a good credit risk for Ule to offer a loan. According to WeLab co-founder Simon Loong, a former banker, 64 per cent of rural Chinese have no access to banks, and store owners lack the credit history to borrow. So his business evaluates them with data from credit bureau and social apps, but also from their mobile devices. "We've processed five million members, and haven't lost a case in fraud," Loong explains. Shop owners can take unsecured cash loans at nine per cent APR and use them to buy stock from Ule; the postal bank provides the cash. And shop customers give WeLab's WeLend business access to a vast amount of mobile data for a loan decision within five minutes.

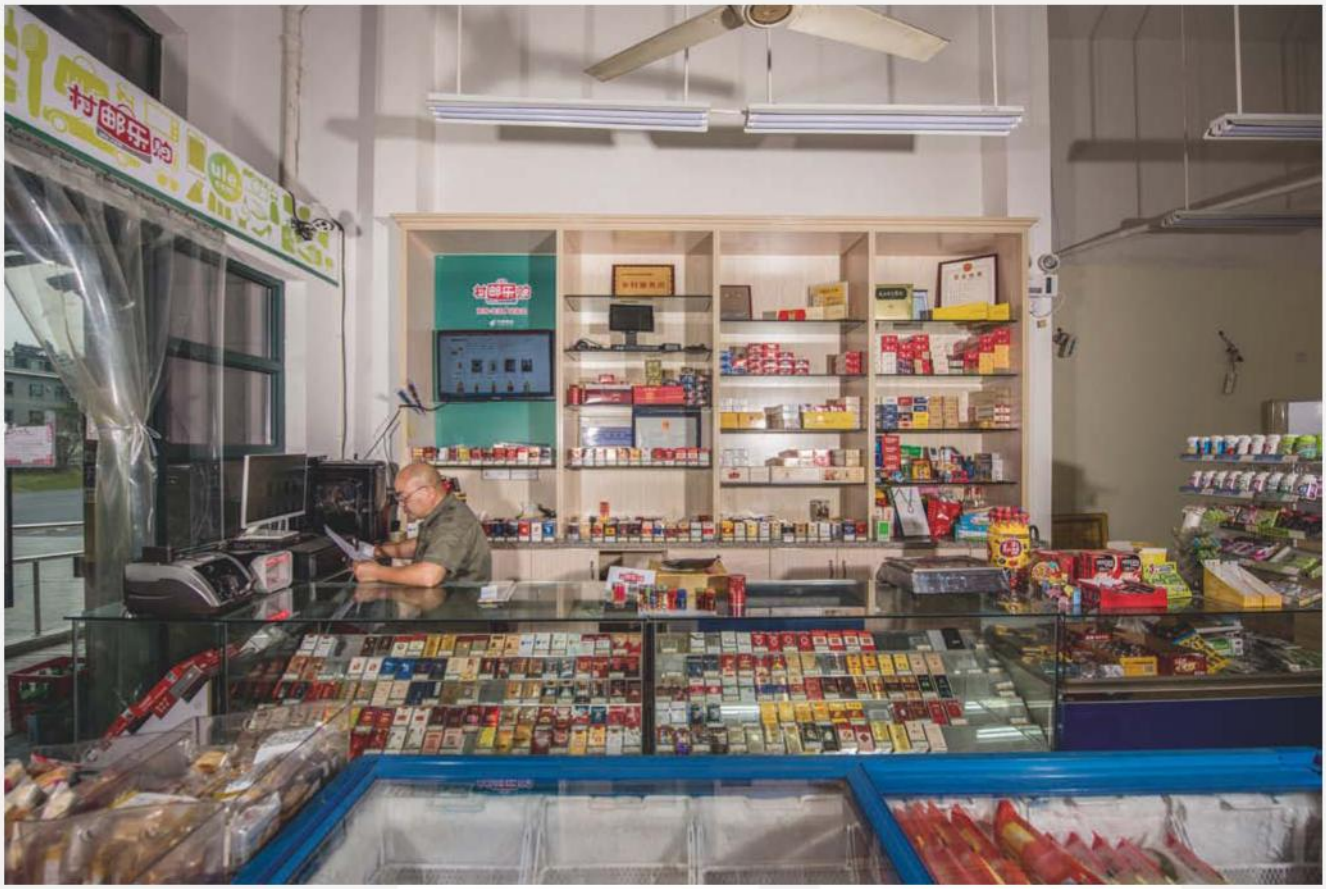
"We look for personality traits, level of responsibility, by collecting 800 data points," Loong explains. "The model of phone, your apps, how you interact with others, the structure of your social networks, how you fill in your address. Whether you use capital letters correlates with bankruptcy – we think that's education level. Even what time you apply affects credit performance: 1am to 6am applicants are more likely to be bad customers compared with 8am to 1pm. We work with telcos to measure inbound call frequency, the longest gap and variability between calls – as very talkative customers are not good borrowers. We even look at messaging, and connections between the phone numbers of poor credit users – as they influence each other." Prospective customers are also asked to take a selfie, which is matched using face recognition to the police ID system. "We aspire to provide affordable credit to 30 per cent of China by 2018," Loong says.

And so a country-wide retail-data and logistics business is also building a data-led money-lending division to oil the wheels of commerce.

"What the hell is a Toronto-based data company doing in Hangzou?" Rubikloud's Liu reflects. "You can't ignore the world's largest consumer market. A cookie company we talked to missed their forecast by $50 million in ten major cities, because they underestimated local demand for other brands, got the pricing wrong and mistargeted promotions. Today they need a Ule – competition is too high. It's very difficult to predict demand: one company lost $100 million this year because it had no visibility of demand. They need a more real-time system." That comes down to knowing who the customers are, what they are buying, and where. "Ultimately we want to sell real-time placement in the physical store," Liu says. "Nielsen, dunnhumby – they're up for disruption."

Top: Qiu and her husband Lu Gen Fu, who is a carpenter, in their Ule-logo-decorated store

Bottom: Staff at Ule's Yuhang district warehouse, which has moved to a bigger site three times in two years



Top: Lou Wener gives villagers access to thousands of additional online goods via the postman

Bottom: Han Guo Min in his store, which brings in the equivalent of £800 daily, despite being outside the city

Left: Chen Qing, Ule chairman and China Post general manager, photographed by WIRED in Beijing

"THIS IS INNOVATION FROM CHINA. It's China IP. Internet companies are copying us." Chen Qing, founding member and chairman of Ule, as well as China Post's general manager in the province, is explaining over a lunch that includes snake soup (like bony white fish, actually) how he's modernising a million-person, 150-year-old enterprise that stretches from a postal savings bank to insurance.

"Ule is a major weapon, a catalyst, for China Post renewal," Chen, 50, continues. "To change a culture, you need to use innovative tech and a market-driven mindset. Our parcel business has grown 450 per cent in this province because of Ule. Now I demand at least 100 per cent growth every year. I've been with China Post for 20 years. I've never failed. I won't fail this one."

Zhejiang province was chosen as the test bed for Ule because it's an established e-commerce hub: Alibaba is based in Hangzhou, as are more than a third of China's e-commerce sites, according to the *Hangzhou Daily*. And now, Chen says, it's ready to roll out nationally – with central- and regional-government backing. "The government is endorsing Ule, to back its rural policy, for instance, subsidising the capex of each store to upgrade computers and encouraging farmers to list produce on Ule," he explains. "Seventy per cent of the population is rural and there are lots of gaps: how do rural people get quality goods? How do farmers sell back to cities efficiently? Then there's information asymmetry. If you harvest when everyone else is, your price can collapse. China Post is the only entity in China that has complete coverage down to the last mile. We want to use tech to solve those problems."

Plus, of course, it's very good for business to reinvent China Post as the backbone of a national retail-commerce transport network. "The main China Post business gets a significant uplift, with boosts to the financial business and the logistics business," Chen explains. "Our transactions on Ule will soon exceed 200 billion RMB. The farmers get more business, which creates more logistics volume for us and more cash on deposit for the postal bank. In 2015, the postal bank had 150 billion RMB in cash deposits. In 2016, it was 200 billion. Ule has contributed half of that growth."

In 2017, he says, the goal is to connect 500,000 rural stores. "After that, the next 500,000 will be urban. Imagine anyone in a city being able to order organic greens from farmers via Ule. We have cold storage – so we'll deliver to the neighbourhood shop in the city. And think of the benefit to the farmer." In the city today, Chen explains, ginger is selling for 6RMB per half a kilo, of which the farmer gets 1.5RMB. "We will pay the farmer 3RMB and then sell it on Ule for 4.5RMB. China Post provides the lending capital, Ule provides sales and we all share the profit."

There is the small matter of persuading postal workers to upgrade from bicycle to minivan. And also ensuring that the workers buy the vans. "We're encouraging postmen to borrow money from the postal bank to buy their vans," Chen says, enthusiastically. "China Post outsources delivery to them, even as employees, and subsidises their gas. But staff own the car. He'll take good care of his own car! They get extra income for delivering wholesale goods. No other postal service is doing this!" He grins. "Changing people is disruptive. You need to change their brain."

And if workers refuse to buy their van? "All staff are Communist Party members," he says solemnly. "We have no unions here. They know what is in the best interests of China." He smiles. "Or – I can move them to another job."

"IT'S HOW COMMUNISM STARTED. THE revolution began with the farmers." Ken Yeung, brother of Samson, is explaining how Ule's particular model will solve China's "rural problem" before scaling fast to the cities. Yeung is the Hong Kong-based CEO of the TOM Group and an enthusiast of his time at Singularity University. He is walking past stacked boxes of Wahaha water, Victory Vitamin Water, El Sotillo wine, Funkid Grapefruit Juice, Red Tea and a thousand other SKUs of snacks, sauces and toiletries in a 550-square-metre former letter-sorting warehouse in Yuhang county that's about to be replaced by one five times the size. This is one of 400 China Post warehouses across China that work with Ule to stock village stores directly. Local specialities include lotus fruit, sausage and duck. Food authenticity is guaranteed.

"This morning they've processed 80 orders, which we deliver in the afternoon," says Yeung, scrolling through a PC in the order-processing room. "We analyse data patterns, and work with suppliers to get bulk discounts," he says. "The biggest retail chain in China, Sinopec, has 25,000 gas stations with convenience stores. After that there's a gap. So we're using technology to give retailers cheaper prices on cookies, shampoo, noodles..."

The TOM Group, which owns 42 per cent of Ule, "is here to empower China Post", which owns 43.7 per cent. "We put in people with a tech background and they run ground operations," he says. "We were running eBay in China. We understand e-commerce. So we're digitising retail. We have feedback from 300,000 retailers. Postmen travel to 15 villages daily, so we roll out fast."

The results are demonstrable. Ule's gross merchandise value in the first half of 2016 was 28.2 billion RMB, a threefold increase on the previous year. Politicians are coming to pay their respects: Wang Yang, one of China's vice-premiers, visited JiuDu township, Sichuan, in May with Lu Jiajin, Postal Savings Bank president. "Alibaba is also trying to connect the last mile," Yeung says. "They thought they'd have 200,000 outlets after two years. They have just 17,000 after 18 months.

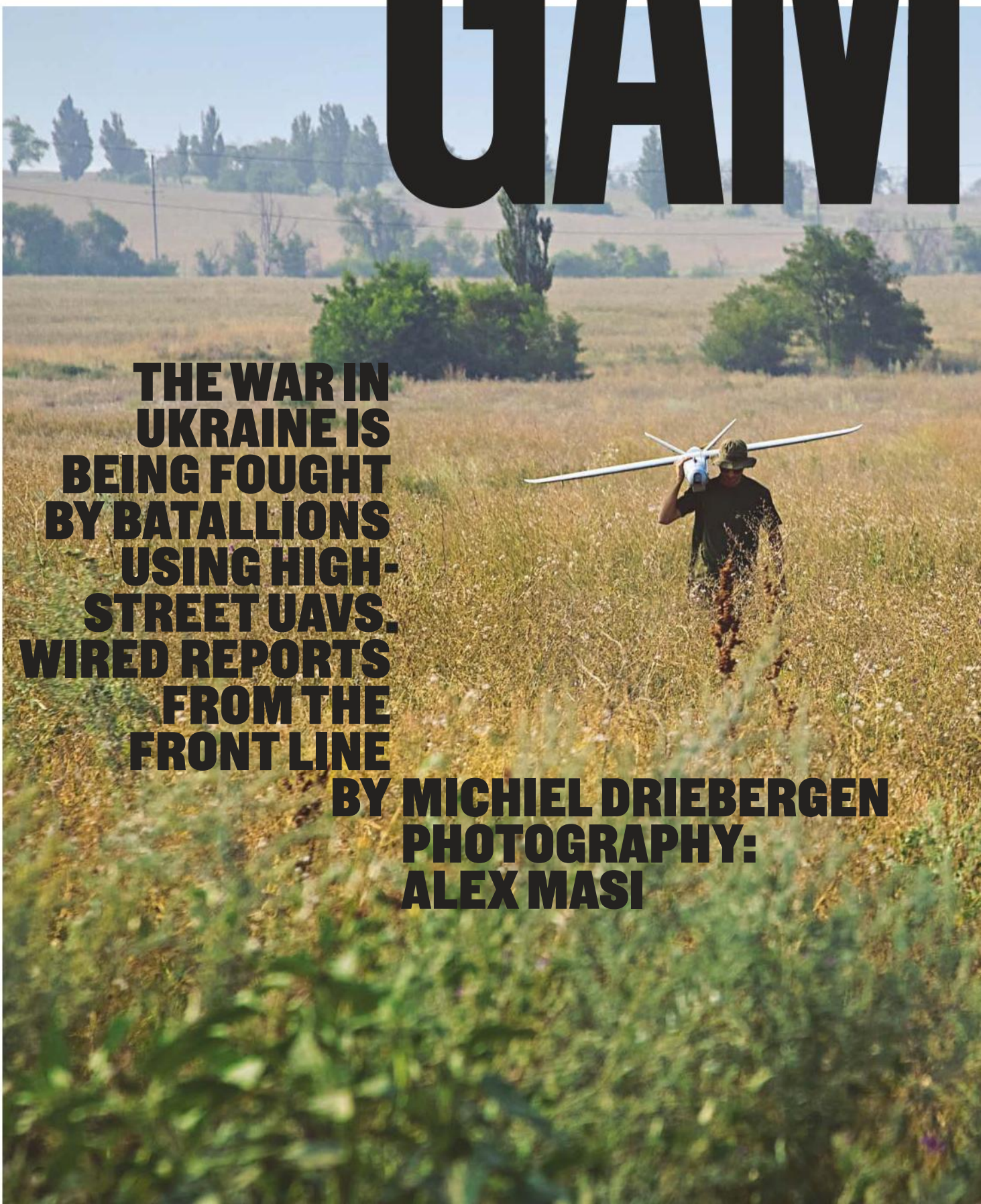
"But Alibaba is a transaction company. Ule is a data company."

David Rowan is editor of WIRED. *He wrote about China's most inventive startups in issue 04.16*

Left: Qiu Sai Zhen shows products to her customers on her smartphone via a *WeChat* group featuring 115 people

Above: Ken Yeung, CEO of the TOM Group, photographed by WIRED in the village of Zan Gong

GAM



THE WAR IN UKRAINE IS BEING FOUGHT BY BATALLIONS USING HIGH-STREET UAVS. WIRED REPORTS FROM THE FRONT LINE

BY MICHIEL DRIEBERGEN
PHOTOGRAPHY: ALEX MASI

E OF DRONES

Do you see that?" asks a heavily built soldier everyone calls Master. "The heavy artillery is getting closer. They are only six kilometres away. We are within their range now."

Master is wheezing from the effort of launching an unmanned aerial vehicle (UAV). Its owner bellows, "Three, two, one – go!" The drone – which measures about one metre by one metre – shoots off, propelled by an engine that buzzes energetically. For a short time it's possible to follow its progress out over the sea, but pretty soon it's out of sight.

Now Master and another fighter sit on two small folding chairs, mesmerised by the images on two small monitors in the open boot of their 4x4. Bird, as Master has fondly named the plane, sends back real-time images of an area it would be impossible for either of the men to reconnoitre: the other side of the front line. The images reveal fields full of craters of various sizes. Beyond them, there are trenches in a zigzag pattern. These are enemy positions.

"Bird flies a course preprogrammed by us," Master says. "But during the flight, we can adjust its path, vary the altitude and make the camera turn in any direction. We can zoom in as well."

The incoming images are razor sharp; way down below, treetops sway in the wind and a flock of birds swarms by.

Flying is Master's hobby. Two and a half years ago, when fighting broke out in eastern Ukraine with the Russian Federation, he quit his job as a policeman and joined the Donbas Battalion, an army unit of volunteers. He applies his past experience as a pilot when he reconnoitres the front line with UAVs, and offers any information he collects to the army.

Today, the men are situated in a field on a cliff by the sea, ten kilometres east of the port of Mariupol. The front line – a village named Shyrokyne – lies nearby, below them. It's not visible but, from time to time, it's possible to hear an explosion. "Don't worry, they can't see us," Master says.

"Look, a BMP," Master's comrade says excitedly. The men readjust their camera and stare intently at the screen. Sure enough, the infantry fighting vehicle – known as a BMP – has been located, half-buried ready for an ambush. BMPs are illegal under the Minsk Agreement – a document, signed in 2014, intended to end the fighting in the Donbass region of Ukraine. Further down, behind the village, they spot more tank-like vehicles.

Master isn't willing to reveal if Ukraine is also using forbidden weaponry, but the images from the drone show craters around Russian trenches. There is a lot of shooting going on, from both sides.

This zone near Mariupol has been the scene of heavy fighting in the past few months. The soldiers call this artillery bombardment "the concert" as it happens in the dark. As soon as the controllers of the Organization for Security and Co-operation in Europe (OSCE) – an international monitoring group – leave the area at night, the heavy weapons come out. Then there's non-stop firing from both sides until dawn.

Ukraine's belief is that the Russians want to seize Mariupol to create a land connection between Crimea – which has been annexed by Russia – and the rebel territories in southeast Ukraine.

"Last night we had to deal with 122mm mortar shells and – to judge by the size of the splinters – tank fire," says Volodymyr Hrynyuk, deputy commander of the Eighth Army battalion. His unit of about 400 men is stationed around the village of Hranitne, 50 kilometres north of Mariupol. Each night, a section of his soldiers mans the trenches at the front line. "At night we must be on standby at our positions, ready to defend ourselves, if necessary."

Now, in the daytime, his men rest at the army base. Or, if they are in their battle positions, they

Previous page: a volunteer with a militia group recovers a landed drone. **Right:** Master and his team set up to launch a drone near Berdyans'ke, southeast Ukraine

Above: Master prepares to launch a drone. The visual data collected from it of pro-Russia separatists' positions will be used by his team in collaboration with the Ukrainian army and volunteers' groups in southeast Ukraine

clean and maintain their weapons and shore up the earthen trench walls with wooden stakes.

Hrynyuk and his unit have neither drones nor reconnaissance planes as the Ukrainian army has a shortage of the most basic equipment.

"With a drone it would be so much easier to observe the enemy and pinpoint their weaponry," he says. "That reduces the risk of our men being killed by shelling." There have been no fatalities since his unit deployed, he says, but they have only been in the area for a month.

The frustrating part is that the enemy has access to this kind of technology. "We consistently see them flying overhead," he says. "When we do, we can almost be sure that, two hours later, our positions will be bombed."

Indeed, the following night, every Ukrainian position is attacked. The explosions are deafening and shrapnel splinters fly through the air. The soldiers huddle, waiting in the trenches for the bombardment to finish.

Returning fire is difficult. "Without drones, our army is blind," Master says. Hrynyuk's men are forced to locate the enemy positions in the old-fashioned way: on foot, by sending out reconnaissance patrols. "That entails walking large distances and risking our lives to detect the enemy positions. A reconnoitre takes two days. With a drone you can have much more information within two hours," Hrynyuk says.

After two flights, Master and his colleagues pack it in for that afternoon. "We immediately pass on any information we gather to the leaders of the battalion nearby. They can then take decisions," he says. "It's no secret that we are dealing with

Master isn't willing to reveal if Ukraine is using forbidden weaponry, but the images from the drone show craters around Russian trenches. There's a lot of shooting going on, from both sides

Above: a soldier discusses the morning's enemy movements from the trenches on the front line of Hranitne, near Mariupol, southeast Ukraine

Russian armed forces. They have more resources and material. He who sees the enemy first wins."

Far from the front, in his workshop in the capital city of Kiev, 31-year-old drone technician Aleksandr is busy screwing parts of a UAV together. "The war is not like the second world war – that is, pitching one massive force against another," he says. "Today it is about taking the right positions and manoeuvring based on incoming information about the whereabouts of your enemy."

Aleksandr comes from Stakhanov, a town in the region that has now been occupied by pro-Russian militias. For that reason, he doesn't want to reveal his family name or have his photo taken: "This is to protect my family." With two colleagues, Aleksandr runs a company that assembles and repairs drones. It was originally for business clients, but his clients now include the army.

Aleksandr points to his computer screen. "Look how buildings have been destroyed," he says. You can see drone images of the outskirts of Avdiivka, a city of Donetsk – the militias' capital. "People used to live here, but now these buildings have been blown to bits and only their skeletons remain."

The drone that Aleksandr is repairing is a common consumer drone – in-store it would cost €1,000 (£900). The UAV can fly at 200 metres with a range of five kilometres. But it's different from the retail version: Aleksandr has modified the drone. "Where a civilian drone can't fly any more, ours still works. The mechanisms are similar but we make changes to its electrical systems. What we do exactly, that's a secret."

Unlike Master's unmanned aircraft, which maps entire areas and costs €12,000, these drones are mainly used to fly to a specific point, take photos and return straight away.

The Ukrainian army depends on volunteers such as Aleksandr to provide them with UAVs. They help to collect money for their acquisition and any repair work necessary if the vehicles are damaged.

"Fortunately, this drone returned," he says. "But often they don't. It takes off, but once in sight of the enemy, there's a 'boom' and then it bursts into a thousand little chips."

Because most soldiers have no experience with drones, Aleksandr also offers training. "In the early 2000s, the army had a fully functioning division dedicated to unmanned reconnaissance flights," Aleksandr says. "But that unit disappeared before the conflict with Russia started."

In Ukraine, it's generally assumed that Russia's secret service has been infiltrating the army for years in order to weaken it. Many official army

'The war is not like the second world war... Today it is about taking the right positions and manoeuvring based on incoming information about the whereabouts of your enemy'

Above: a soldier using binoculars to watch over the front line

Below: Master and his team set up signal transmission poles for the drone they prepare to launch

units surrendered without resistance to the pro-Russian militias as soon as the conflict began.

"When the fighting erupted, it quickly became apparent that we were needed," Aleksandr says. He works six days a week, and is, by his own account, compelled to put his own money into the reparation of the drones. "We've never had any support from the Ministry of Defence or the army," he says.

"We can't do anything without volunteers," Master says. His "bird" was donated to the battalion by the Victory Sisters Foundation, which has donors in the UK. But the drone pilot adds that it's becoming difficult to find sponsors. "Many people are fed up with the war and are short of money because of the crisis." Aleksandr agrees: "Organising a collection, targeted at funding a drone for a battalion, for instance, is the only thing that still works. But it's time-consuming."

The most motivated volunteers come from the regions occupied by militants. "I've been attacked, so I have to defend myself," Aleksandr says. After the war broke out, he fled with his family to Kiev. "During a drone mission last autumn, I had just a glimpse of my city, far away on the horizon. But a drone can't narrow that distance for me."

In this, the third year of conflict in eastern Ukraine, Aleksandr's drones have become increasingly visible in the combat zone. "In the airspace over the Donbas region it's like a drone party in full swing," Alexander Hug, who heads the OSCE mission, said in September 2016. The group doesn't fly unmanned aircraft any more because they're shot down. As a result, exercising any supervision over the use of heavy weapons has become practically impossible.

"Military drones have a great future," Aleksandr says. "Drones have no fear and are capable of executing almost any task the army requires. That's something the government should think about." He is convinced that, in the future, wars will be fought with unmanned aerial vehicles.

For now, the army has to deal with the everyday reality of limited resources: the front line is hundreds of kilometres long and drone teams such as Master's are scarce. Frustration is mounting on the front line. "It's exhausting for soldiers to be bombarded daily by artillery fire," Master says. "There have been examples of boys being blown up by mines. Some lose their nerves and break; they have to be demobilised."

"We feel as if our hands are tied," adds Hrynyuk. "In principle, we comply with the Minsk Agreement. But sometimes we have to return fire, to save the lives of our soldiers."

"We achieve nothing by signing ceasefires and Minsk Agreements, anyway," Aleksandr sighs. "We have to use violence to recover our territory, that is the only option. But how? I don't know."

He pats the drone affectionately. "I give him kisses and love and then I send this drone back to the east again. You'll see, as soon as it gets there, it'll show some defects again. Sometimes it seems they don't want to return to the front line." ■

Michiel Driebergen is a freelance journalist based between Krakow, Poland, and Lviv in Ukraine

Below: Master handles an unmanned surveillance aircraft two kilometres from front line town Shyrokyne in southeast Ukraine

At 14, he started his first business. At 23, he began making millions for Enron. At 28, he launched his own hedge fund. At 33, he became the youngest billionaire in America. At 38, he retired. John Arnold's next mission?

Photography: Brent Humphreys

By Sam Apple

WAGING WAR ON BAD SCIENCE

1

Brian Nosek had pretty much given up on finding a funder. For two years he had sent out grant proposals for his software project. And for two years they had been rejected again and again – which was, by 2011,

discouraging but not all that surprising to the 38-year-old scientist. An associate professor at the University of Virginia, Nosek had made a name for himself in a hot sub-field of social psychology, studying people's unconscious biases. But that's not what this project was about. At least, not exactly.

Like a number of up-and-coming researchers in his generation, Nosek was troubled by mounting evidence that science itself – through its systems of publication, funding and advancement – had become biased towards generating a certain kind of finding: novel, attention-grabbing, but ultimately unreliable. The incentives to produce positive results were so great, Nosek and others worried, that some scientists were simply locking their inconvenient data away.

The problem even had a name: the file-drawer effect. And Nosek's project was an attempt to head it off at the pass. He and a graduate student were developing an online system that would allow researchers to keep a public log of the experiments they were running, where they could register their hypotheses, methods, workflows and data as they worked. That way, it would be harder for them to go back and cherry-pick their sexiest data after the fact – and easier for other researchers to replicate the experiment later.

Nosek was so taken with the importance of redoing old experiments that he had also rallied more than 50 like-minded researchers across the country to participate in something he called the Reproducibility Project. The aim was to redo about 50 studies from three prominent psychology journals to establish an estimate of how often modern psychology turns up false positive results.

It was little wonder, then, that funders didn't come running to support Nosek: he wasn't promising novel findings, he was promising to question them. So he ran his projects on a shoestring budget, self-financing them with his own earnings from corporate-speaking engagements on his research.

But in July 2012, Nosek received an email from an institution whose name he didn't recognise: the Laura and John Arnold Foundation. A Google search told him that the Arnolds were a young billionaire couple in Houston, Texas. John, Nosek learned, had made his first millions as a wunderkind natural-gas trader at Enron, the infamous energy company, and he'd managed to walk away from Enron's 2001 collapse with a seven-figure bonus and no accusations of wrongdoing attached to his name. After that, Arnold started his own hedge fund, Centaurus Energy, where he became, in the words of one hedge-fund competitor, "The best trader that ever lived, full stop." Then Arnold abruptly retired at the ripe age of 38 to focus full-time on philanthropy.

As Nosek tells it, John Arnold had read about the Reproducibility Project in *The Chronicle of Higher Education* and wanted to talk. By the following year, Nosek was co-founding an institution called the Center for Open Science with an initial $5.25 million (£4.3m) grant from the Arnold Foundation. More than $10 million more in Arnold Foundation grants have come since. "It transformed what we could imagine doing," Nosek says. Projects that Nosek had once envisioned as modest efforts carried out in his lab were now being conducted on an entirely different scale at the centre's startup-like offices in downtown Charlottesville, with some 70 employees and interns churning out code and poring over research. The skeletal software behind the data-sharing project became a slick cloud-based platform, which has now been used by more than 30,000 researchers.

The Reproducibility Project, meanwhile, swelled to include more than 270 researchers working to reproduce 100 psychology experiments – and in August 2015, Nosek revealed its results. Ultimately his army of volunteers could verify the findings of only about 40 per cent of the studies. Media reports declared the field of psychology, if not all of science, to be in a state of crisis. It became one of the biggest science stories of the year.

But as it happens, Nosek is just one of many researchers who have received unsolicited emails from the Arnold Foundation in the past few years – researchers involved in similar rounds of soul-searching and critique in their own fields, who have loosely amounted to a movement to fix science.

John Ioannidis was put in touch with the Arnolds in 2013. A childhood maths prodigy turned medical researcher, Ioannidis became a kind of godfather to the science reform crowd in 2005, when he published two devastating

PREVIOUS PAGE: GROOMING BY KRISTIN DANIELL

papers – one of them titled simply *Why Most Published Research Findings Are False*. Now, with a $6 million initial grant from the Arnold Foundation, Ioannidis and his colleague Steven Goodman are setting out to turn the study of scientific practice – known as meta-research – into a fully-fledged field in its own right, with a new research centre at Stanford.

British doctor Ben Goldacre also received an email from the Arnold Foundation in 2013. Known as a sharp-witted scourge of "bad science", Goldacre spent years building up a case that pharmaceutical companies, by refusing to reveal all their data, have essentially deceived the public into paying for worthless therapies. Now, with multiple grants from the Arnolds, he is leading an effort to build an open, searchable database that will link all publicly available information on every clinical trial in the world.

A number of the Arnolds' reform efforts have focused on fixing nutrition science. In 2011, science journalist Gary Taubes received an email from Arnold himself. Having spent more than a decade picking apart nutrition science, Taubes soon found himself co-founding an organisation with a substantial grant from the Arnold Foundation to rebuild the study of obesity from the ground up. And in 2015 the Arnold Foundation paid journalist Nina Teicholz to investigate the scientific review process that informs the US Dietary Guidelines. Just weeks before the federal guidelines were due for an update, Teicholz's blistering report appeared in the prominent medical journal *BMJ*, charging that the government's panel of scientists had failed to consider evidence that would have done away with long-held worries about eating saturated fat.

And those are just a few of the people who are calling out iffy science with Arnold funding. Laura and John Arnold didn't start the movement to reform science, but they have done more than anyone else to amplify its capabilities – typically by approaching researchers and asking whether they might be able to do more with more money. "The Arnold Foundation has been the Medici of meta-research," Ioannidis says. All told, the foundation's Research Integrity initiative has given more than $80 million to science critics and reformers in the past five years alone.

Not surprisingly, researchers who don't see a crisis in science have started to fight back. In a 2014 tweet, Harvard psychologist Daniel Gilbert referred to researchers who had tried and failed to replicate the findings of a senior lecturer at the University of Cambridge as "shameless little bullies". After Nosek published the results of his reproducibility initiative, four social scientists, including Gilbert, published a critique of the project, claiming, among other things, that it had failed to accurately replicate many of the original studies. The *BMJ* investigation, in turn, met with angry denunciations from nutrition experts who had worked on the US Dietary Guidelines; a petition asking the journal to retract Teicholz's work was signed by more than 180 credited professionals. (After an external and internal review, *BMJ* published a correction but chose not to retract the investigation.)

The backlash against Teicholz also furnished one of the few occasions when anyone has raised an eyebrow at the Arnolds' funding of science critics. On the morning of October 7, 2015, the US House Agriculture Committee convened a hearing on the controversy surrounding the dietary guidelines, fuelled by the *BMJ* article. For two and a half hours, a roomful of testy representatives asked why certain nutrition studies had been privileged over others. But about an hour in, Massachusetts representative Jim McGovern leaned into his microphone. Aiming to defend the science behind the guidelines, McGovern suggested that the doubts that had been cast over America's nutrition science were being driven by a "former Enron executive". "I don't know what Enron knows about dietary guidelines," McGovern said. But "powerful special interests" are "trying to question science".

McGovern's quip about Enron, a company that hasn't existed for 15 years, was a bit of a potshot. But given the long history of deep-pocketed business interests sowing doubt in research, his underlying question was a fair one: who is John Arnold, and why is he spending so much money to raise questions about science?

2

***Fortune* magazine once described** Arnold as "one of the least-known billionaires in the US". His profile in the public consciousness is almost non-existent, and he rarely gives interviews. But among hedge funders and energy traders, Arnold is a legend. John D'Agostino, former head of strategy of the New York Mercantile Exchange, says that in Arnold's heyday, people in the industry would discuss him in "hushed and reverent tones". In 2006, Centaurus reportedly saw returns of more than 300 per cent; the next year Arnold became the youngest billionaire in the country. "If Arnold decided he wanted to beat hunger," D'Agostino says, "I wouldn't want to bet on hunger."

For all the swagger of that description, Arnold himself has virtually none. He is universally described as quiet and introspective. At Enron, a company famous for its brash, testosterone-laced cowboy culture, the perennially boyish-looking trader was reportedly so softly spoken that his colleagues had to gather in close to hear him at restaurants. "People would read into it, and they would say he's just being cagey," D'Agostino says. "And then, after a couple of years, people were like, 'Oh, no, he's actually like that.'"

Arnold is still quiet. "Usually the division of labour in most of our work is that I talk," Laura Arnold says in a phone interview. By all accounts, Laura, who attended Harvard College and Yale Law School and worked as an oil executive, has been equally influential in setting the direction for the foundation. But when WIRED visits the Arnold Foundation's Houston headquarters in June, Laura has been called away on a family emergency, leaving John to do the talking. Arnold is 175 centimetres tall, trim and

'IF ARNOLD DECIDED HE WANTED TO BEAT HUNGER I WOULDN'T WANT TO BET ON HUNGER'
– JOHN D'AGOSTINO

conventionally good looking, his youthful appearance now somewhat concealed by a salt-and-pepper beard.

Arnold grew up in Dallas. His mother was an accountant (she would later help manage the books at his hedge fund). His father, who died when Arnold was 18, was a lawyer. By preschool, Arnold's talent for mathematics was apparent. "I think I was just born with a natural gift for seeing numbers in a special way," he says. Gregg Fleisher, who taught him calculus in high school, recalls an occasion when Arnold instantly solved a maths puzzle that had been known to stump PhDs. But he also stood out for his scepticism. "He questioned everything," Fleisher says.

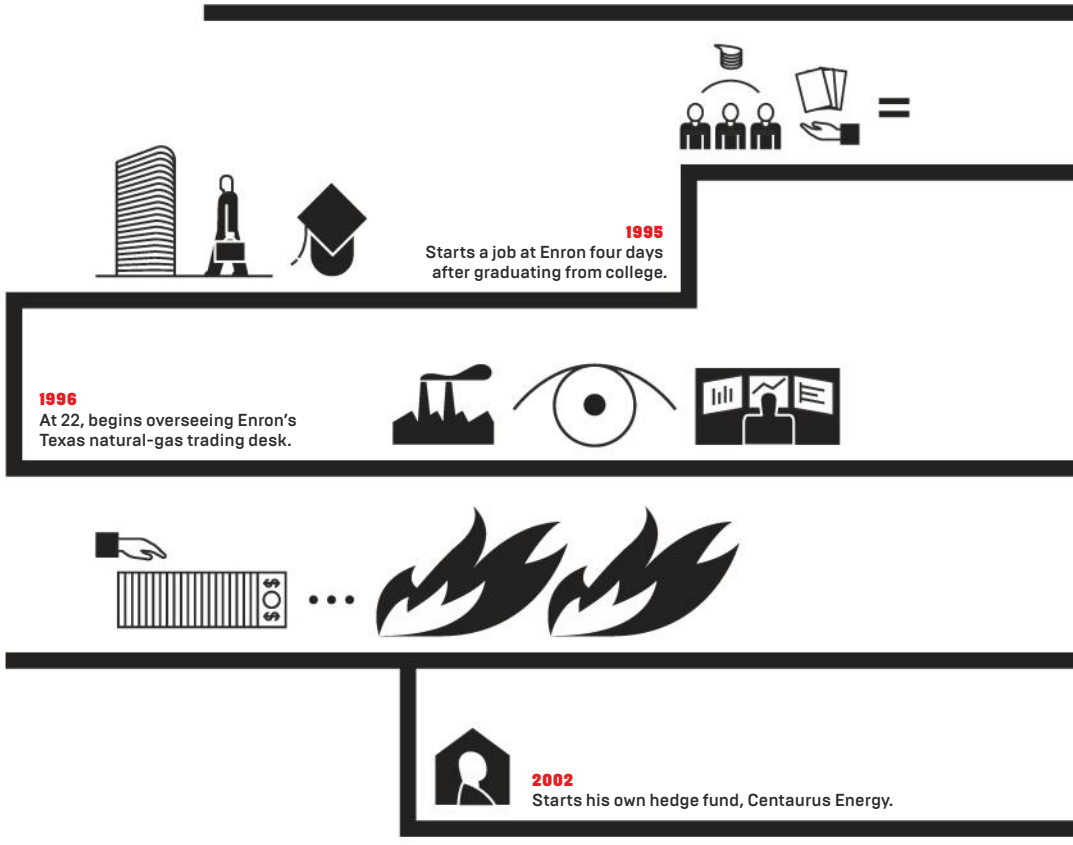
By the time he was 14, Arnold was running his first company, selling collectible sports cards across state lines. Those were the early days of the internet, and he managed to gain access to an online bulletin board intended only for card dealers. The listings let him see that the same cards were sold at different prices in different parts of the country – which presented an opportunity for arbitrage. "Hockey cards didn't have much of a market in Texas," he tells me. "I would buy up all the premium hockey cards and send them to Canada or upstate New York." He called the company Blue Chip Cards. Arnold estimates that he made $50,000 before he finished high school.

Arnold graduated from Vanderbilt University in 1995, taking only three years to finish his degree. He started working at Enron four days later. A year after that, at age 22, he was overseeing Enron's Texas natural-gas trading desk, one of the company's core businesses.

Arnold's work at Enron – seeking to capitalise on seasonal price differences in natural gas – wasn't all that different from what he'd done as a teenager selling sports cards. In *Hedge Hogs*, a 2013 book about hedge-fund traders, Jeff Shankman, another star trader at Enron, is quoted describing Arnold as "the most thoughtful, deliberate and inquisitive person" he worked with. But Shankman recognised that he and Arnold were different in one key respect: Arnold had a greater appetite for risk. On some days at Enron, Arnold would trade more than a billion dollars' worth of gas contracts. In 2001, even as Enron was collapsing amid an accounting scandal that covered up billions in debt, he was reported to have earned $750 million for the company. A former executive at Salomon Brothers later told *The New York Times* that there were very few incidents in the history of Wall Street comparable to Arnold's success.

BURN BRIGHT

John Arnold's brief but legendary career in finance MARLEY WALKER



As Enron neared bankruptcy, executives scrambled to hold its operation together, offering bonuses to keep traders on board. Arnold was given $8 million, the biggest payout of all, just days before Enron filed for bankruptcy. He started Centaurus the following year, bringing along a small group of former Enron traders who worked out of a single large room.

Arnold says he wasn't sure if he could match the success he'd enjoyed as a futures trader at Enron. As a pipeline company, Enron had a direct view on many of the factors that influence gas prices. Now he'd have to rely purely on his prowess with data. By law, natural-gas pipelines had to make much of their information public, and around the time Centaurus was forming, more of that information began to appear online. "A lot of people didn't know it was out there," Arnold says. "People who did, didn't know how to clean it up and analyse it as well as we did."

It wasn't long before Arnold had the answer to his doubts. In 2006, Centaurus reportedly generated a 317 per cent return overall, after taking the opposite side of a risky bet that another hedge fund, Amaranth, had made on fluctuations in natural gas prices. Amaranth, which was gambling with money from large pension funds, suffered a $6 billion loss and collapsed. By 2009, Centaurus was managing more than $5 billion and had more than 70 employees. In its first seven years, according to *Fortune*, the fund never returned less than 50 per cent.

But Arnold had to come down to earth eventually. In 2010, Centaurus experienced its first annual loss. And though the fund bounced back the next year, tighter regulations on trading and a far less volatile market made it unlikely that Arnold would again see the astonishing returns of only a few years earlier. And so, at

1988
Starts his first company at the age of 14, selling collectible sports cards across state lines.

2001
Pulls in a reported $750 million for Enron even as the company goes down in flames.

2006
Goes head-to-head with a rival hedge fund, which loses and collapses; Centaurus boasts a 317 per cent annual return.

2007
Becomes the youngest billionaire in the US at 33 years old.

2010
After seven years of reportedly yielding 50 per cent returns or higher, Centaurus experiences its first annual loss.

the age of 38, Arnold walked away from it all. He announced that he was closing Centaurus in a letter to investors: "After 17 years as an energy trader, I feel that it is time to pursue other interests."

Arnold tells me that he had lost some of his passion for trading. At the time, his net worth was estimated to be around $3 billion. In 2010 the Arnolds had signed the Giving Pledge, promising to give away at least half their wealth – and he wanted to be as strategic about that goal as he had once been about trading. Arnold has said that the first phase of his life was "100 per cent trying to make money" and that it's now "100 per cent trying to do good". As *The Wall Street Journal* noted, in "US history, there may have never been a self-made individual with so much money who devoted himself to philanthropy at such a young age".

3

The Arnolds had been dabbling in philanthropy for years, supporting a few handpicked programmes in education, criminal justice reform and other areas that were important to them. But now, with their stepped-up ambitions, the couple entered a new realm. Arnold had always been ready to make huge bets, but it was his hunger for reliable data that made him a brilliant trader. That same hunger would make large-scale philanthropy more challenging than he had anticipated.

In a glass conference room at the Arnold Foundation's offices – which occupy the same space as the old Centaurus trading floor – Arnold explains that his and Laura's initial plan had been to simply locate the most effective organisations and write them cheques. But figuring out which organisations were most effective turned out to be vexing. Nonprofits are good at reporting their success rates, but dig into their claims and you find that they often omit relevant context or confuse correlation with causation. "The more you read the research, the less you know," Arnold says.

"It became frustrating." Then, one day in November 2011, he was listening to the podcast *EconTalk*, hosted by libertarian economist Russ Roberts. The guest that day was science journalist Gary Taubes, and he was talking about how the prevailing dietary wisdom of the past 40 years – that eating too much fat leads to obesity and heart disease – arose from the flimsiest of scientific evidence. The foundational studies, Taubes said, looked at the diets and disease rates in various countries, then essentially guessed at which items in the diet were responsible for the country's good or bad health statistics. Worse yet, whenever evidence came along that contradicted the consensus about the dangers of eating fat – often evidence that was much stronger than the evidence for the dangers – it was ignored or not even published. Hardly anyone in the world of nutrition science seemed willing to question the science behind the low-fat diet, even after westerners grew fat and diabetic in record numbers. The picture Taubes painted wasn't of a flawed study here or there but of a fundamentally broken scientific culture.

During the podcast, Taubes mentioned that he was raising money in the hope of funding experiments that might deepen our understanding of the root causes of obesity. Not long after the podcast went online, he received a five-line email from Arnold. "From the little I know about the science of nutrition, your study makes a lot of sense," Arnold wrote. Like Nosek, Taubes had to Google Arnold to learn who he was. Six months later, the Arnold Foundation made a $4.7 million seed grant to the Nutrition Science Initiative (NuSI), the nonprofit Taubes co-founded to support fundamental research on diet and health. The next year the Arnolds promised another $35.5 million. Arnold is careful not to lump all researchers together when he talks about the problems in science. But he tells WIRED that listening to Taubes and reading his book, *Good Calories, Bad Calories*, had been an "aha moment" for him. "Science is built like a building," Arnold says. "One floor on

2012
Arnold closes shop and retires from Centaurus at the age of 38, dedicating himself to strategic philanthropy.

top of the next." In nutrition, "the whole foundation of the research had been flawed. All these things that we thought we knew – when we step back and look at the evidence base – it's just not there."

Arnold says that now, unless he trusts a researcher's work, he no longer believes the findings of any scientific study until he or someone on the staff carefully vets the paper.

Together with Taubes' work, Arnold was also reading Ioannidis's and Goldacre's equally devastating analyses. These critiques of science amounted to a deep philosophical quandary for the Arnolds, philanthropists who had dedicated their lives to a data-based approach to giving. "In everything they do, they want to be evidence-driven," says Stuart Buck, vice president of research integrity at the Arnold Foundation. But if you look at the studies that can't be reproduced and other issues facing science, "you start to think: 'What is evidence? What do we actually know?'"

The Arnolds had already decided that, with decades of life ahead of them and almost unlimited resources, they had the time and money to evaluate charitable programmes properly, even when that meant paying for expensive randomised controlled trials that could take years to complete. But now they were widening their scope. If they wanted to embark on truly "transformational change", as their foundation literature states, it wouldn't be enough to properly evaluate this or that education or criminal justice programme. They would also have to take on a far more ambitious project: the Arnolds would have to try and fix science itself.

JOHN AND LAURA ARNOLD'S ARMY OF SCIENCE REFORMERS

Science is broken. Here are some of the prominent people trying to fix it – with funding from the Arnold Foundation. MW

Tim Errington
Cancer biologist
Starting a project to redo a large number of cancer studies and see how many hold up to replication.
Center for Open Science funding: $1.9 million

Ben Goldacre
Doctor
Creating a searchable online repository of data from all the world's clinical trials.
Center for Open Science funding: $590,000

Brian Nosek
Psychologist
Runs the Center for Open Science, a major hub of the science-reform movement, which pushes for transparency and mounts efforts to replicate studies.
Arnold funding: $17.6 million

John Ioannidis and Steven Goodman
Medical professors
Launched a new Stanford centre dedicated to meta-research – the study of the practice of science.
Arnold funding: $6 million

Gary Taubes
Journalist
Helped set up and run a research centre called the Nutrition Science Initiative to investigate the causes of obesity.
Arnold funding: $29 million

Nina Teicholz
Journalist
Investigated the science behind the US Dietary Guidelines for a report published in the *BMJ*.
Arnold funding: $15,000

4

In their philanthropy, the Arnolds like to say, they follow data where it leads rather than let themselves be guided by ideology. And it's true that, when it comes to political leanings, they are somewhat hard to pin down. The Arnolds identify as Democrats and were major financial supporters of Barack Obama. In 2013 they donated $10 million to keep Head Start, the early-childhood education programme for low-income kids, running through the federal government shutdown, and many of the issues they've taken on, from criminal justice reform to making prescription drugs more affordable, are decidedly progressive. Yet the foundation is also focused on reforming what the Arnolds see as a broken public-pension system – a project that, in practice, usually means cutting payments to retirees, raising retirement ages and switching new workers to 401(k)-style plans. That focus led *Rolling Stone* to call Arnold a "young right-wing kingmaker with clear designs on becoming the next generation's Koch brothers."

If John Arnold does have an identifiable ideology, it is that of a lifelong trader and quantitative analyst: unsentimental, metrics-focused, interventionist. He is unapologetic about having worked at Enron, and he can be defensive about the moral standing of Wall Street in the public mind. In 2015, after a cancer researcher was found to have falsified research data and defrauded the government out of millions of dollars, Arnold complained on Twitter that the penalty, a five-year funding restriction, was too light. Had something similar happened on Wall Street, he tweeted, the perpetrator would have been sentenced to ten years in jail and the bank would have been fined a billion dollars. "Is there something special about frauds in the securities biz that they should be penalised infinitely more harshly than other business frauds?" he went on. "Or is Wall Street an easy target while cancer researchers and universities are not?"

So it's no surprise that, in practice, the Arnolds' approach to giving has a lot in common with John Arnold's approach to investing. Laura says she sees her husband's appetite for risk –

an appetite she says she shares – as the most obvious link between his approach to trading and philanthropy. Once the foundation has identified areas where they believe they can make the biggest difference, they go all in. "We're not looking to create an organisation of safe success," she says. "We're looking to create an organisation of thoughtful failure and fantastic success."

Arnold is, in at least one respect, trying to make science a little more like finance. In recent decades, maths and science whizzes such as Arnold have invaded Wall Street, bringing a level of scientific precision to trading and often making fortunes in the process. And good traders, as Arnold sees it, naturally come to appreciate something that researchers too often miss: it's very easy to be fooled by your own data. They internalise the risk of mistaking correlation for causation – not because they're smarter than scientists but because they have money riding on the outcome. "As a general rule, the incentives related to quantitative research are very different in the social sciences and in financial practice," says James Owen Weatherall, author of *The Physics of Wall Street*. "In the sciences, one is mostly incentivised to publish journal articles, and especially to publish the sorts of attention-grabbing and controversial articles that get widely cited and picked up by the popular media. The articles have to appear methodologically sound, but this is generally a lower standard than being completely convincing. In finance, meanwhile, at least when one is trading with one's own money, there are strong incentives to work to that stronger standard. One is literally betting on one's research."

In conversations with Arnold and his grantees, the word incentives seems to come up more than any other. The problem, they claim, isn't that scientists don't want to do the right thing. On the contrary, Arnold says he believes that most researchers go into their work with the best of intentions, only to be led astray by a system that rewards the wrong behaviours. "Scientists really do want to discover things that make a difference in people's lives," says Goodman. "In a sense, that's the strongest weapon that we have. We can feed off that." Figuring out exactly what rewards work best and how to simultaneously change the incentives for researchers, institutions, journals and funders is now a key area of interest for Goodman and Ioannidis.

RESEARCHERS HAVE THE BEST OF INTENTIONS, BUT THE SYSTEM REWARDS THE WRONG BEHAVIOURS

At the Center for Open Science, Nosek has already begun to experiment with new incentives for scientists. Because investigating and replicating research begins with having the data and materials necessary to do so, he is focused on making science more transparent. In 2014 he partnered with the journal *Psychological Science* to offer colourful "Open Data" and "Open Materials" badges for papers that met specific criteria for sharing. A 2016 study to determine the effectiveness of the badges showed that the number of articles that reported publicly available data had increased tenfold. "It's a stupid little badge," Nosek says, but it works.

Nosek is also still campaigning to convince researchers to preregister what they plan to analyse and report in a study, so that they can't adjust their experiment on the fly or hide less-than-dazzling results – a problem that Goldacre is also tackling. To promote preregistration, the Center for Open Science offered the first 1,000 scientists who preregister their studies with the organisation $1,000 each. Nosek says that the cash offers were Arnold's idea.

Denis Calabrese, the Arnold Foundation's president, says they don't expect immediate results. The Arnolds have a "multiple-decade timeline to work on problems". Yet the most remarkable thing about the Arnold Foundation's research integrity projects is that they already appear to be paying off. For one thing, the problems plaguing scientific research are now increasingly well known. Of 1,576 researchers who responded to a recent online survey from *Nature*, more than half agreed there is "a significant crisis" of reproducibility. The comedian John Oliver spent 20 prime-time minutes on HBO last May mocking the reign of terrible science on TV news shows and in public debate: "After a certain point, all that ridiculous information can make you wonder: 'Is science bullshit?' To which the answer is clearly no, but there's a lot of bullshit masquerading as science." (Some of the background footage in the segment came from the Arnold Foundation.)

Ioannidis, whose name is almost synonymous with scientific scepticism, says he has seen immense progress in recent years. The journals *Science* and *Nature* have started bringing in statisticians to review their papers. The National Institutes of Health (NIH) is moving forward with new requirements for data sharing; starting as early as this year, all NIH-funded training programmes must include plans for teaching researchers the principles of reproducibility. "Now everybody says we need replication; we need reproducibility," Ioannidis says. "Otherwise our field is built on thin air."

The Center for Open Science's next undertaking is another reproducibility project – this one for cancer studies. In 2012, the former head of cancer research at the biotech firm Amgen revealed the results of the company's effort to replicate 53 "landmark" papers in hematology and oncology; only six studies' findings could be confirmed. So there is already widespread concern about reproducibility in the field. The centre's replication efforts, in turn, have inspired economists and even tropical ecologists to plan reproducibility projects of their own.

Whether all this momentum will lead to transformational change decades from now is impossible to know. Arnold figures that some of his specific grants might not work out as planned. (The foundation's funding of the Nutrition Science Initiative is now scheduled to end in November.) More generally, it may not be possible to truly reform a system where the incentives are already so deeply embedded. "It's probably too big a lift for us to expect we're going to change researchers who have been around for decades," he says. Plus, systems of prestige and advancement die hard. "You don't shift a culture overnight," Nosek says. But as many Wall Street veterans can testify, betting against John Arnold is usually a bad idea. ■

Sam Apple teaches science writing at the University of Pennsylvania

OVERHEARD THIS MONTH

"What's this overdue China feature *actually* about?" "Well, it's got a really great opening line..."

"Basically, we need a tear in the fabric of time and space, which is sucking in all of reality." – simple instructions for an illustration commission.

Journalists: pitch stories to editorial @wired.co.uk
PRs: contact us at pr@wired.co.uk
Reader feedback: rants@wired.co.uk

"I'd like to point out that all this was predicted by *Battlestar Galactica*." – a nuanced editorial discussion on how AI will doom us all.

"It's very Mr C, and I mean that as a compliment."

"We have some suggestions for your section. Some you'll love, some you *might* feel a bit funny about..."

"These shots from the surface of Mars aren't high-res enough. Can we send a photographer?"

"Those people spend their days thinking about the end of humanity – so we should probably do serious portraits."

"Of course it's comfortable – it was made for Depeche Mode!" – high praise for the WIRED editor's carbon-fibre chair.

"I would like to see the word 'extrusion' in the headline. It's not an order. Just a preference."

"If humans can't be trusted with cutlery, we definitely can't be trusted with cars."

HOW THE WORLD ENDS THIS MONTH

2017 has barely begun, but we're already looking to the future – or lack of. Here's what our staff see bringing about the end:

Twitter
Self-driving cars
Southern Rail
José Mourinho
Donald Trump

REJECTED HEADLINES THIS MONTH

Linguine-meenie-minie-mo
Pasta la vista, baby
Heeeeeey... macaroni!
Penne from heaven

SAD FACES THIS MONTH

According to Tom Vanderbilt (Ideas Bank, p41), the emoji taps into basic human cognitive architecture in conveying complex feelings with a simple symbol. So when we were planning this issue's cover we came up with these rather panicky looking iterations before landing on a reassuring smiley. Perhaps everything will be fine after all...

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Published by The Condé Nast Publications Ltd, Vogue House, Hanover Square, London W1S 1JU (tel: 020 7499 9080; fax: 020 7493 1345). Colour origination by Altaimage London. Printed in the UK by Wyndeham Roche Ltd. WIRED is distributed by Condé Nast & National Magazine Distributors Ltd (Comag), Tavistock Road, West Drayton, Middlesex UB7 7QE (tel: 01895 433600; fax: 01895 433605). A one-year (10 issues) WIRED magazine subscription is available to the UK, Europe, US and the rest of the world. Order at www.magazineboutique.co.uk/wired/W173 or call +44 (0)844 848 5202, Mon-Fri 8am-9.30pm, Sat 8am-4pm. Enquiries, change of address and orders payable to WIRED, Subscription Department, Lathkill St, Market Harborough, Leics LE16 9EF, United Kingdom. Change of address or other subscription queries: email wired@subscription.co.uk or call 0844 848 2851. Manage your subscription online 24 hrs a day at www.magazineboutique.co.uk/youraccount. The paper used for this publication is based on renewable wood fibre. The wood these fibres are derived from is sourced from sustainably managed forests and controlled sources. The producing mills are EMAS registered and operate according to highest environmental and health and safety standards. This magazine is fully recyclable - please log on to www.recyclenow.com for your local recycling options for paper and board. WIRED is a member of the Independent Press Standards Organisation (which regulates the UK's magazine and newspaper industry). We abide by the Editors' Code of Practice [www.ipso.co.uk/editors-code-of-practice] and are committed to upholding the highest standards of journalism. If you think that we have not met those standards and want to make a complaint please see our Editorial Complaints Policy on the Contact Us page of our website or contact us at complaints@condenast.co.uk or by post to Complaints, Editorial Business Department, The Condé Nast Publications Ltd, Vogue House, Hanover Square, London W1S 1JU. If we are unable to resolve your complaint, or if you would like more information about IPSO or the Editors' Code, contact IPSO on 0300 123 2220 or visit www.ipso.co.uk

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THE WIRED INDEX

1,007

The number of identical robots that danced together at a beer festival in Shandong, China, setting a world record for the most robots moving simultaneously

34%

Proportion of US adults who would be enthusiastic about using chips to enhance their brains, according to a Pew Research Center poll

73%

Proportion of US adults who think such enhancements will further increase inequality in society, as they will only be affordable for the very wealthy

£70

The amount by which HTC increased the UK price of its Vive VR headset, from £689 to £759, in the aftermath of Brexit

17 SECONDS

The time it takes, on average, for drivers to react to an autonomous vehicle's request to take over the wheel, according to a 2015 study by the US National Highway Traffic Safety Administration

930

The number of mouse genes associated with a propensity for alcoholism, according to a study by researchers from Purdue and Indiana University

1,700,000 YEARS

The age of the oldest known human cancer, an osteosarcoma found on a hominid bone in South Africa

40 PER CENT

Energy saved by its data centres after Google's DeepMind assessed its consumption patterns

3 YEARS

Amount of time it will still take for mathematicians to verify a 500-page mathematical proof, a 2012-published solution to the *abc* conjecture about whole numbers, according to its author, Shinichi Mochizuki

2021

The year in which computer transistors are expected to stop shrinking, thus putting an end to Moore's law, according to the International Technology Roadmap for Semiconductors

4.5X

Increased risk of death to cardiovascular disease among astronauts who have taken part in Nasa's Apollo missions

$64,650

Salary offered (plus benefits) by the Smithsonian Institution's National Museum of American History for the position of beer historian. The successful candidate requires a sound knowledge of the craft industry

WORDS: GIAN VOLPICELLI; ILLUSTRATION: GIACOMO GAMBINERI; SOURCES: WWW.PEWINTERNET.ORG; HTC VIVE; NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION; SAJS.CO.ZA; NATURE.COM; PLOS GENETICS; SEMICONDUCTOR INDUSTRY ASSOCIATION; SMITHSONIAN INSTITUTION'S NATIONAL MUSEUM OF AMERICAN HISTORY

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