Imperial College London

TABLE OF DISRUPTIVE TECHNOLOGIES

A dashboard of 100 wonderful, weird (and possibly worrying) ways the world might change in the foreseeable future

POTENTIAL FOR SOCIO-ECONOMIC DISRUPTION ↑ HIGH ↓ LOW

De Digital footprint eraser 91 DE	**Ps** Personal digital shields 92 DE	**Ht** Human head transplants 93 HA	**Hc** Human cloning & de-extinction 94 HA	**Da** Distributed autono-mous corporations 95 DE	**Sp** Space solar power 96 SP	**El** Space elevators 97 SP	**Vr** Fully immersive virtual reality (VR) 98 DE	**Co** Artificial consciousness 99 EA	**Qt** We can't talk about this one 100
Ci Conversational machine interfaces 81 MI	**Le** Life-expectancy algorithms 82 DE	**Sa** Stratospheric aerosols 83 SP	**Br** Battlefield robots 84 EA	**Ad** AI advisors & decision-making machines 85 DE	**Ab** AI board members & politicians 86 EA	**Is** Invisibility shields 87 SP	**Ph** Factory photosynthesis 88 SP	**Th** Transhuman technologies 89 HA	**Te** Telepathy 90 HA
Ss Planetary-scale spectroscopy 71 SP	**Ip** Implantable phones 72 MI	**He** e-tagging of humans 73 DE	**Mp** Male pregnancy & artificial wombs 74 HA	**Dn** DNA data storage 75 DE	**Gv** Genomic vaccines 76 SP	**Qs** Quantum safe cryptography 77 DE	**Cp** Cognitive prosthetics 78 HA	**Ud** Data uploading to the brain 79 HA	**Rd** Reactionless drive 80 SP
Gh Predictive gene-based healthcare 61 DE	**Ak** Automated knowledge discovery 62 EA	**Rs** Autonomous robotic surgery 63 EA	**Em** Emotionally aware machines 64 MI	**Xx** Humanoid sex robots 65 MI	**Bh** Human bio-hacking 66 HA	**Me** Internet of DNA 67 DE	**Tc** Thought control - machine interfaces 68 MI	**Dr** Dream reading & recording 69 HA	**Wh** Whole Earth virtualisation 70 DE
Md Mega-scale desalination 51 SP	**Sw** Self-writing software 52 EA	**Mm** Public mood monitoring 53 DE	**Pb** Programmable bacteria 54 SP	**Et** Peer-to-peer energy trading & transmission 55 DE	**La** Lifelong personal avatar assistants 56 MI	**Sd** Smart dust 57 DE	**Lc** Low-cost space travel 58 HA	**Pc** Planet colonization 59 HA	**Sh** Shape-shifting matter 60 SP
Mc Medical tricorders 41 DE	**Sf** Smart flooring & carpets 42 DE	**Dt** Diagnostic toilets 43 DE	**Se** Smart energy grids 44 SP	**Bf** Algal bio-fuels 45 SP	**Op** Human-organ printing 46 SP	**Bs** Artificial human blood substitute 47 SP	**Nm** New materials 48 SP	**Fu** Fusion power 49 SP	**Mr** Self-reconfiguring modular robots 50 SP
Dl Distributed ledgers 31 DE	**Pa** Precision agriculture 32 SP	**Av** Autonomous vehicles 33 EA	**Id** Intention decoding algorithms 34 MI	**Df** Drone freight delivery 35 EA	**Ap** Autonomous passenger aircraft 36 EA	**Fp** 3D-printing of food & pharmaceuticals 37 SP	**Sr** Swarm robotics 38 EA	**Fd** 4-dimensional materials 39 SP	**Ze** Zero-point energy 40 SP
Rc Robotic care companions 21 MI	**Sc** Smart controls and appliances 22 DE	**Cm** Cultured meat 23 SP	**Ro** Delivery robots & passenger drones 24 EA	**As** Autonomous ships & submarines 25 EA	**Rg** Resource gamification 26 SP	**Wa** Water harvesting from air 27 SP	**Eb** Broadcasting of electricity 28 SP	**Bp** Bio-plastics 29 SP	**Be** Beam-powered propulsion 30 SP
Cr Cryptocurrencies 11 DE	**So** Concentrated solar power 12 SP	**Pp** Predictive policing 13 DE	**Eh** Micro-scale ambient energy harvesting 14 SP	**Wt** Airborne wind turbines 15 SP	**Ac** Avatar companions 16 MI	**Mh** Metallic hydrogen energy storage 17 SP	**Sg** Smart glasses & contact lenses 18 HA	**Pe** Pollution eating buildings 19 SP	**Ff** Force fields 20 SP
Sn Smart nappies 1 DE	**Dw** Deep ocean wind farms 2 SP	**Va** Vertical agriculture 3 SP	**We** Wireless energy transfer 4 SP	**Bi** Balloon-powered internet 5 SP	**Px** Powered exoskeletons 6 HA	**Cc** Computerized shoes & clothing 7 DE	**Vt** Vacuum-tube transport 8 SP	**Sj** Scram jets 9 SP	**Am** Asteroid mining 10 SP

SOONER ← TIME* → LATER

Example of organizations active in each area

1 Monit (South Korea), Abena Nova (Denmark), Siempre Secos (Spain)

2 Statoil (Norway), Siemens (Germany), Volturn (US), UMaine (US)

3 Green Skies Vertical Farms (US), Aero Farms (US), Neo Farms (Germany), Urban Crop Solutions (Belgium)

4 WiTricity (US), Powermat (Israel), Apple/Power By Proxi (US), Qualcomm (US), Mojo Mobility (US), Mopar (US), Fulton Innovation (US)

5 Google/Alphabet (US)

6 ReWalk (US), Rex Bionics (US), SuitX/US Bionics (US), Ekso Bionics (US), Lockheed Martin (US)

7 Google/Alphabet (US), Samsung (Korea), Hexoskin (Canada) Owlet (US), Komodo Tech (Canada), Shiftwear (US), Lechal (India), OM Signal (Canada)

8 The Boring Company/Elon Musk (US), China Aerospace Science and Industry Corporation (China)

9 Reaction Engines (UK), NASA (US), Boeing (US), Lockheed Martin (US), Airbus (France)

10 Deep Space Industries (US), Planetary Resources (US), Made in Space (US)

11 Bitcoin (Japan), Ripple (US), Litecoin (US)

12 Solarreserve (US), Abengoa (Spain), North China Power Engineering (China), Shanghai Electric (China), Zhejiang Supcon Solar (China), NWEPDI (China)

13 PredPol (US), ECM Universe (US)

14 Pavegen (UK), ECEEN (China)

15 Google/Alphabet (US), Joby Energy (US), Altaeros (US), Kitegen (Italy), Enerkite (Germany)

16 Pullstring (US), Amazon (US), Alphabet/Google (US), Nintendo (Japan), Invisible Girlfriend/Boyfriend (US)

17 NASA (US)

18 Alphabet/Verily (US), Amazon (US), Vuzix (US), Everysight (Israel)

19 Elegant Embellishments (Germany), iNova (Spain), Studio Roosegaarde (Netherlands), Prosolve 370e (Germany)

20 Dstl (UK), Boeing (US)

21 Softbank (Japan), AIST (Japan), Blue Frog Robotics (France), Care-o-bot (Germany), Riken/Sumitomo Riko (Japan), Mayfield Robotics (US)

22 Amazon (US), Google/Alphabet (US), Philips (Netherlands), Samsung (South Korea), Dyson (UK), Miele (Germany), iRobot (US)

23 Impossible Foods (US), Memphis Meats (US), Super Meat (Israel), Finless Foods (US), New Harvest (US)

24 Wing/Alphabet (US), Starship Technologies (UK), Volocopter (Germany), eHang (China), Piaggio (Italy)

25 Leidos (US), Boeing (US), Rolls Royce (UK)

26 Joulebug (US), Waterpebble (UK)

27 Permalution (US), Sun to Water (US)

28 Powercast (US)

29 NatureWorks (US), Gruppo MAIP (Italy), Genomatica (US), Green Dot Bioplastics (US)

30 NASA (US)

31 Everledger (UK), Stampery (Spain), Brickblock (Germany), Slock.it (Germany)

32 Blue River Technology (US), Hortau (Canada)

33 Google/Waymo (US), Voyage (US), Nvidia Automotive (US), most major auto-makers

34 Amazon (US), Google/Alphabet (US), Philips (Netherlands), Samsung (South Korea), Dyson (UK), Miele (Germany), iRobot (US)

35 Google/Alphabet (US), Amazon (US), Flirtey (US)

36 Airbus (France), Boeing (US)

37 FabCafe (Japan), NASA (US)

38 SRI International (US)

39 Stratasys (US), Autodesk (US)

40 NASA (US)

41 Basil Leaf Technologies (US), Dynamical Biomarkers Group (US/Taiwan), Scanadu (US)

42 Starwood Hotels (US), MariCare (Finland), Scanalytics (US), Futureshape (Germany)

43 Flowsky (Japan), Scanadu (US)

44 Tesla (US), ABB (Switzerland), Siemens (Germany), IBM (US), Itron (US)

45 Synthetic Genomics/ExxonMobil (US), Global Algae Innovations (US), Algenol (US)

46 Organavo (US), Envision TEC (Germany), RegenHU (Switzerland), Cellink (Sweden), Seraph Robotics (US)

47 HbO2 Therapeutics (South Africa), Biospace (US)

48 For example Vantaback by Surrey NanoSystems (UK)

49 ITER (EU/France), Tokamak Energy (UK), Alphabet/Google/Tri Alpha Energy (US), General Fusion (Canada), Helion Energy (US), Lockheed Martin (US)

50 Festo (Germany)

51 Israel Desalination Enterprises Technologies (Israel), Acciona (Spain), Fluence Corporation (US)

52 Microsoft (US), Google/Alphabet (US), Open AI (US)

53 Open Utility/Essent (UK/Netherlands), Knowelsys (China)

54 Gingko Bioworks (US), US Naval Research Laboratory (US), US Army Research Lab (US), Darpa (US)

55 Open Utility (UK/Netherlands), Power Ledger (Australia), LO3 energy (US), Energy Web Foundation (Switzerland)

56 Konami Corp (Japan), Mitsuku (UK)

57 MOOG (US), Darpa (US)

58 Space X/Elon Musk (US), Blue Origin (US), Virgin Galactic (UK), Rocket Lab (US), Axiom Space (US), SpaceIL (Israel), Firefly Aerospace (US)

59 Space X (US), UAE Mars Mission (UAE), NASA (US)

60 Intel (US)

61 Kite Pharma/Gilead Sciences (US), 23andMe (US), Phenogen Sciences (US), Regeneron (US), Veritas Genetics (US)

62 IBM (US)

63 Intuitive Surgical (US), Verb Surgical/Alphabet/Johnson & Johnson (US), Da Vinci Surgery (US)

64 IBM (US), Toyota (Japan), Mimosys (Japan), Persado (US), Joy AI (US)

65 Realbotix (US), True Companion (US)

66 BioTeq (UK), Grindhouse Wetwear (US), Dangerous Things (US), see also The Eyeborg Project and the Cyborg Foundation

67 Alphabet/Google Genomics (US), Amazon (US), Illumina (US), Oxford Nanopore Technologies/Metrichor (UK)

68 CTRL-Labs (US), Emotiv (US), Neuralink (US), maybe Facebook (US)

69 No example found

70 Improbable (UK)

71 European Organization for Astronomical Research in the Southern Hemisphere (European consortium of 16 countries)

72 No example found

73 Epicenter (Sweden) and Three Square Market 32M (US) are close

74 No example found

75 Twist Bioscience (US)

76 Vaccinogen (US), EpiVax (US), IBM (US), Juno Therapeutics (US)

77 Alphabet/Google (US), KETS (UK), IDQ (Switzerland), Isara (Canada)

78 Darpa (US)

79 Kernel (US), Neuralink/Elon Musk (US), 2045 Initiative (Russia), Darpa (US), General Electric/Braingate (US), possibly Facebook (US)

80 NASA (US), Cannae (US)

81 Apple (US), Amazon (US), Alphabet/Google (US), Microsoft (US)

82 No example found

83 CIA (US)

84 Lockheed Martin (US), QinetiQ (UK), Boston Dynamics/Softbank (US/Japan)

85 Woebot (US), Pefin (US), LV (UK)

86 Deep Knowledge Ventures (Hong Kong), Tieto (Finland)

87 BAE Systems (UK), Toyota (Japan). NB. Big difference between optical camouflage and bending light to make things disappear

88 Breakthrough Energy (US), RIPE (US), Joint Centre for Artificial Photosynthesis (US)

89 SENS Research Foundation (US), Methuselah Foundation/Peter Thiel (US)

90 Facebook (US), Neuralink/Elon Musk (US)

91 Suicide Machine (Netherlands), Just Delete Me (US)

92 No example found

93 Turin Advanced Neuromodulation Group (Italy)

94 Sooam (South Korea), Revive and Restore (US)

95 No example found

96 Rebeam (US), Solaren Corp (US)

97 Thoth Technology (Canada)

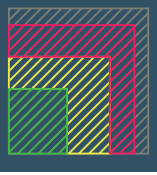
98 Improbable (UK), HelloVR (US), Magic Leap (US), Microsoft (US). See also Mind Maze (US), Facebook (US) and possibly Apple (US)

99 Possibly Alphabet/Google (US)

100 As it says, we can't say

* Time is defined as ubiquity or mainstream use not invention

Legend



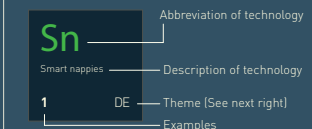
Ghost Technologies: Fringe science & technology. Defined as highly improbable, but not actually impossible. Worth watching.

Horizon 3: Distant future 20 years + (Explore).

Horizon 2: Near future 10-20 years hence (Experiment).

Horizon 1: Happening now (Execute).

How to read entries



Themes

Each of the 100 technologies has been subjectively categorised according to five broad themes, which are:

- DE Data Ecosystems
- SP Smart Planet
- EA Extreme Automation
- HA Human Augmentation
- MI Human-Machine Interactions

The Small Print

Conceived and created by Richard Watson and Anna Cupani at Imperial Tech Foresight. Thanks are due to Gaby Lee, Simon Tindemans, Thomas Heinis, Stephen Green, Peter Childs, Maria Jeansson, Nik Pishavadia, Roberto Trotta, Aifric Campbell, Christopher Haley, Tom Cleaver, Guido Cupani, Gerard Gorman, Finn Giuliani, Lawrence Whiteley, Sebastian Melchor and the Science Communication students at Imperial College London for their invaluable assistance and enthusiasm.

The purpose of this publication is to make individuals and institutions future ready. Also, to make people think, at least periodically.

It is a mixture of prediction and provocation intended to stimulate debate, but be aware that other elements should always be considered when assessing potential impact, especially the wider psychological and regulatory landscape in which technologies exist. Most importantly, the technologies highlighted on this table appear without any discussion of moral or ethical factors. Generally-speaking, no technology should be used unless it improves the human condition and with potentially disruptive technologies always remember that "with great power comes great responsibility". (There are various attributions for this quote ranging from Spiderman, Dr Spock, Yoda, Churchill, Roosevelt and possibly the French Revolution).

Examples are purely illustrative and do not constitute any form of recommendation, validation or investment advice. Also note that with smaller companies and start-ups in particular the landscape is continually changing so treat examples with caution. There will also undoubtedly be errors and misjudgements, so please use a bit of common sense.
If you'd like to contact us to congratulate us, criticise us or buy us lunch our address is techforesight@imperial.ac.uk. You can also reach Richard via richard@nowandnext.com.

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Tech Foresight

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