The Big Read Artificial intelligence

Cyborgs: Elon Musk and the new era of neuroscience

Many labs are trying to connect thought to computers but Neuralink wants to merge AI with the brain

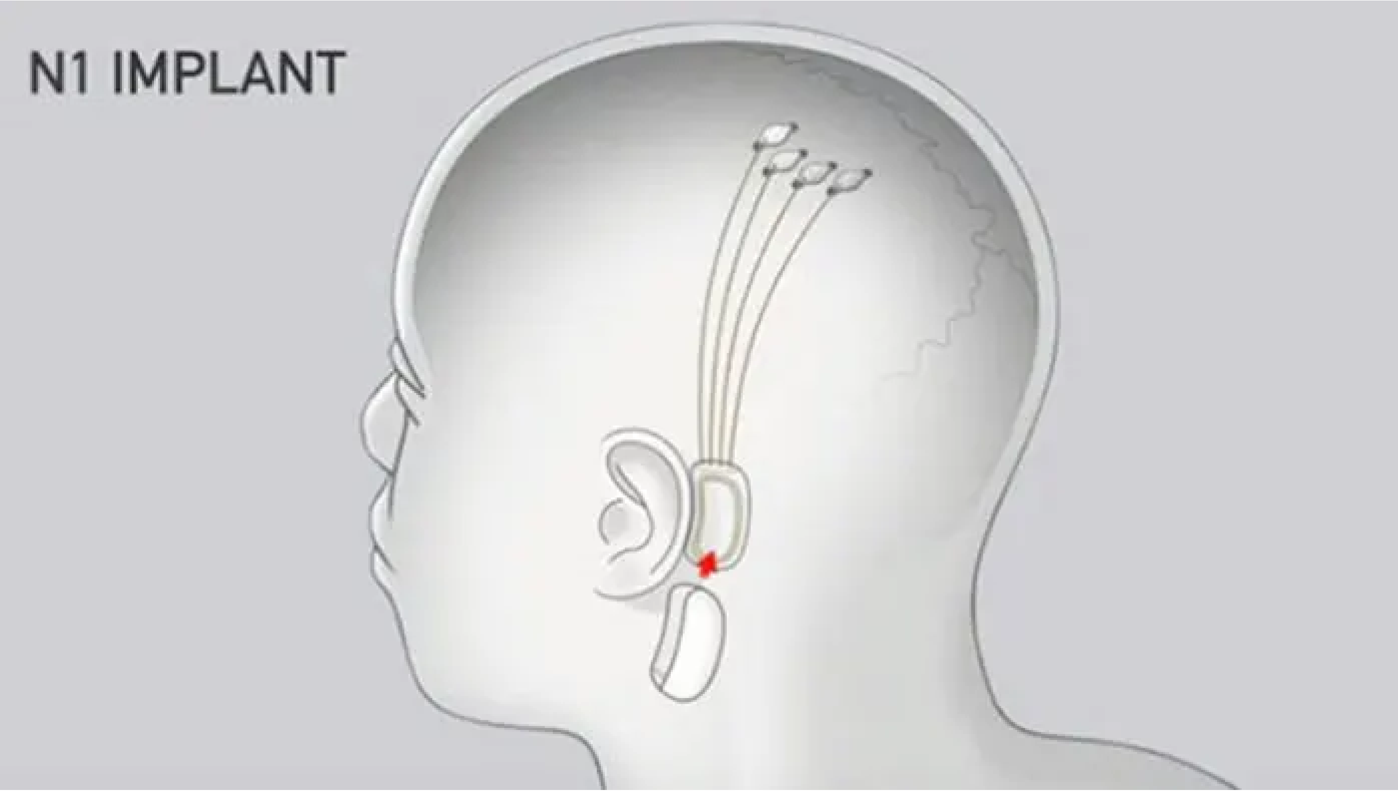
Clive Cookson in London and Patrick McGee in San Francisco JULY 19, 2019

A glitzy presentation in San Francisco this week may go down in history as a giant step in the creation of cyborgs that meld human and machine intelligence. Or it may turn out to be a mere footnote in the career of Elon Musk, the tech showman and entrepreneur extraordinaire.

Mr Musk revealed first details of an electronic brain implant developed by Neuralink, the secretive company he founded in 2016 to facilitate direct communications between people and machines. Its early applications will be in medicine to help people with severely damaged brains or nervous systems. But Mr Musk also emphasised more futuristic plans that can give humans "the option of merging with artificial intelligence" by exchanging thoughts with a computer — augmenting the mental capacity of healthy people.

Neuralink, in which Mr Musk has invested more than $100m, joins the crowded and fast expanding field of neurotechnology, where hundreds of companies and academic labs are developing different types of interface between brains and computers for medical and recreational purposes. It is the only one, however, that flaunts "symbiosis with AI" as a business goal.

Others in the field gave Neuralink a guarded welcome. "Elon is a great promoter," says Thomas Reardon, chief executive of CTRL-Labs in New York. "Hopefully he promotes neural interfaces in a positive way, like he did for electric vehicles at Tesla."



A Neuralink visualisation of how where the electrodes in the brain would connect to a transmitter behind the ear © Neuralink

Neuralink researchers released a 12-page scientific paper with details of their prototype device. Damien Coyle, professor of neurotechnology at Ulster University in the UK, says: "What they are doing is quite impressive. It is novel and radically different to what has been done before but it is still at quite an embryonic state."

The paper describes tests of the Neuralink interface implanted in the brains of rats — and there was a hint during the San Francisco presentation of tests already being carried out on monkeys. The company hopes to get permission from the US Food and Drug Administration to begin a clinical trial in patients with brain damage next year.

Neurotechnology covers a vast range of different techniques. Projecting the market size is difficult and uncertain, though according to Research & Markets, worldwide sales were $8.4bn last year and will grow to $13.3bn in 2022.

The biggest divide is between "invasive" implants such as Neuralink's that are surgically inserted in the brain and "non-invasive" methods that detect and modulate neural activity from outside.

Only invasive implants can provide direct contact with neurons inside the brain — and here Neuralink is a big advance on existing techniques that insert 250 electrodes at most. The company's first experiments inserted 3,000 electrodes into rat brains and it could raise that to 10,000 electrodes in an early clinical version.

A remarkable feat of micro-engineering was required. Neuralink devised a surgical robot to insert the electrodes through small holes in the skull and then weave them through the brain in flexible threads, each thinner than a human hair. The robot has a vision system designed to avoid blood vessels and place the electrodes in specific brain regions. The version for humans will exchange neuronal data between the electrodes and an external computer via a processor with a wireless transmitter implanted behind the ear.

For Mr Musk large numbers of electrodes are essential to provide a fast flow of information to and from the brain. "The thing that will ultimately constrain our ability to [be] symbiotic with AI is bandwidth," he says. "So after solving a bunch of brain-related diseases [the point is] mitigating the existential threat of AI."

The best known implant used for brain-computer research is BrainGate, developed by a US university consortium. Although its devices have far fewer electrodes than Neuralink's, they have achieved some spectacular successes. For example, biomedical engineers at Case Western Reserve University in Cleveland, Ohio, claimed a milestone in neurotechnology in 2017 when Bill Kochevar, paralysed from the neck down for eight years after a cycling accident, became the world's first quadriplegic patient to regain some limb movement electronically.

A BrainGate implant with just two 96-channel electrode arrays, placed on the surface of Mr Kochevar's motor cortex, sent messages to a "functional electrical stimulation" system on his previously immobile arm and hand, replacing his damaged nerves. Small pulses of electricity reanimated his long dormant muscles, enabling him to drink and feed himself again. Similar devices have enabled paralysed patients to move robotic arms and operate computer keyboards through their thoughts.

Leigh Hochberg of Brown University, leader of the BrainGate consortium, called Neuralink's research "a novel and exciting neurotechnology . . . given the great potential that intracortical brain-computer interfaces have to restore neurologic function for people with spinal cord injury, stroke, traumatic brain injury or other diseases or injuries of the nervous system".

Research into implants designed to read patients' thoughts has largely proceeded independently from another important field of invasive brain treatment — "deep brain stimulation", which can help people with Parkinson's disease, epilepsy and depression by sending electric pulses into the areas responsible for their symptoms.

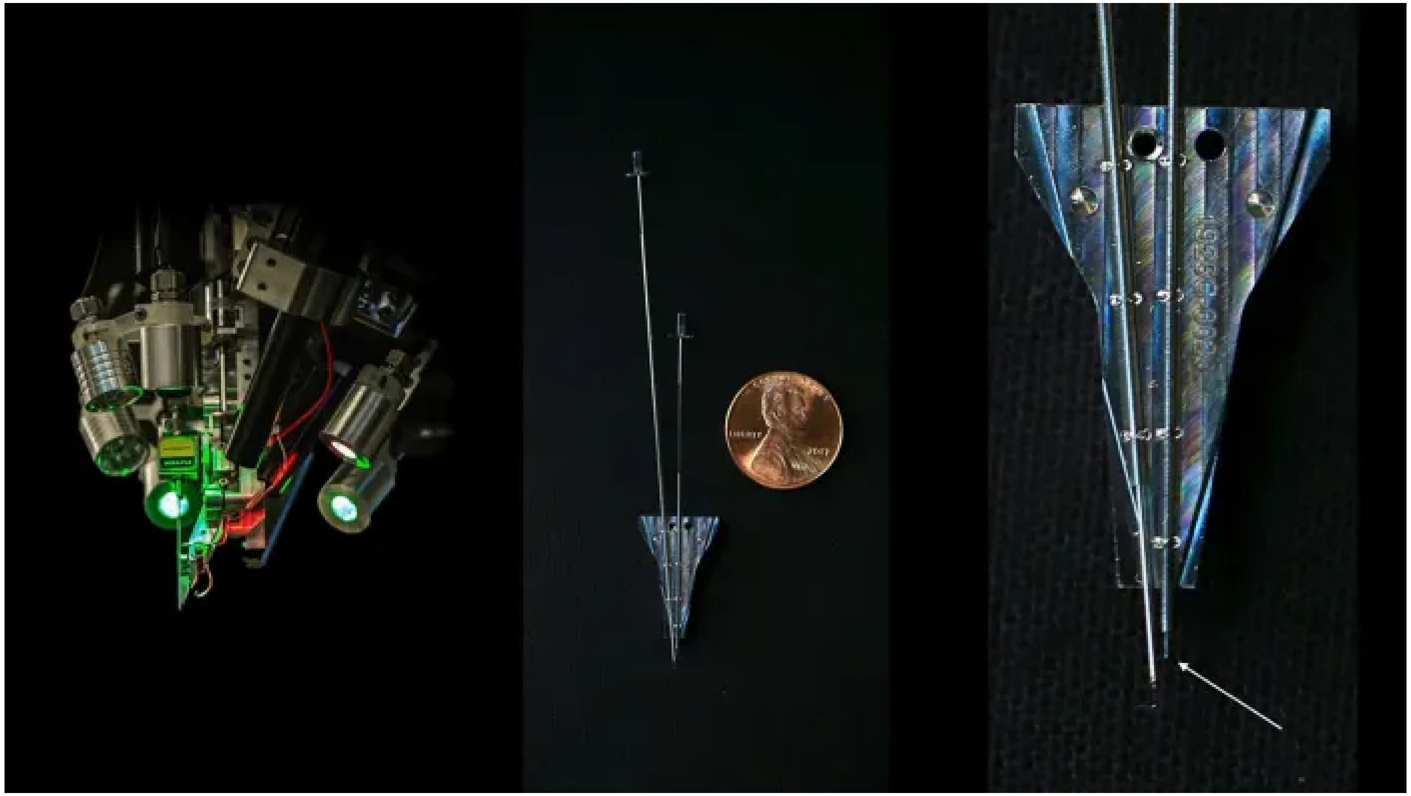
The quadriplegic Bill Kochevar eating with the aid of neural implants © Case Western Reserve University

Until now, the researchers in these two fields have tended to come from slightly different disciplines within the broader study of the brain, which has limited the scope for co-operation, says John Donoghue, director of the Wyss Center for Bio and Neuroengineering in Switzerland. “By working together and sharing information, we can learn from each other and potentially expand the reach of this technology.”

Such collaboration would replace the current one-way DBS systems with “bidirectional electrodes” that both stimulate and record from deep brain structures. They would sense changes in the brain following stimulation and automatically adapt the level of the next pulse accordingly — something that currently has to be done manually.

Another promising field of implant research is to give sight back to people who have gone blind but retain a visual cortex in the brain. For instance, a device called Orion, developed by Second Sight Medical Products of Los Angeles, transmits images from a tiny camera mounted on the wearer's glasses to an implanted array of 60 electrodes.

Researchers at Baylor College of Medicine in Texas reported early trial results last month. "While our subjects describe being able to identify where certain objects are located, right now they are not seeing forms or clear edges," said William Bosking, assistant professor of neurosurgery. "They see a small number of points of light corresponding to where that object is." That is an exciting improvement on their previous total blindness, though hundreds of thousands of electrodes would be required to produce a rich visual image.



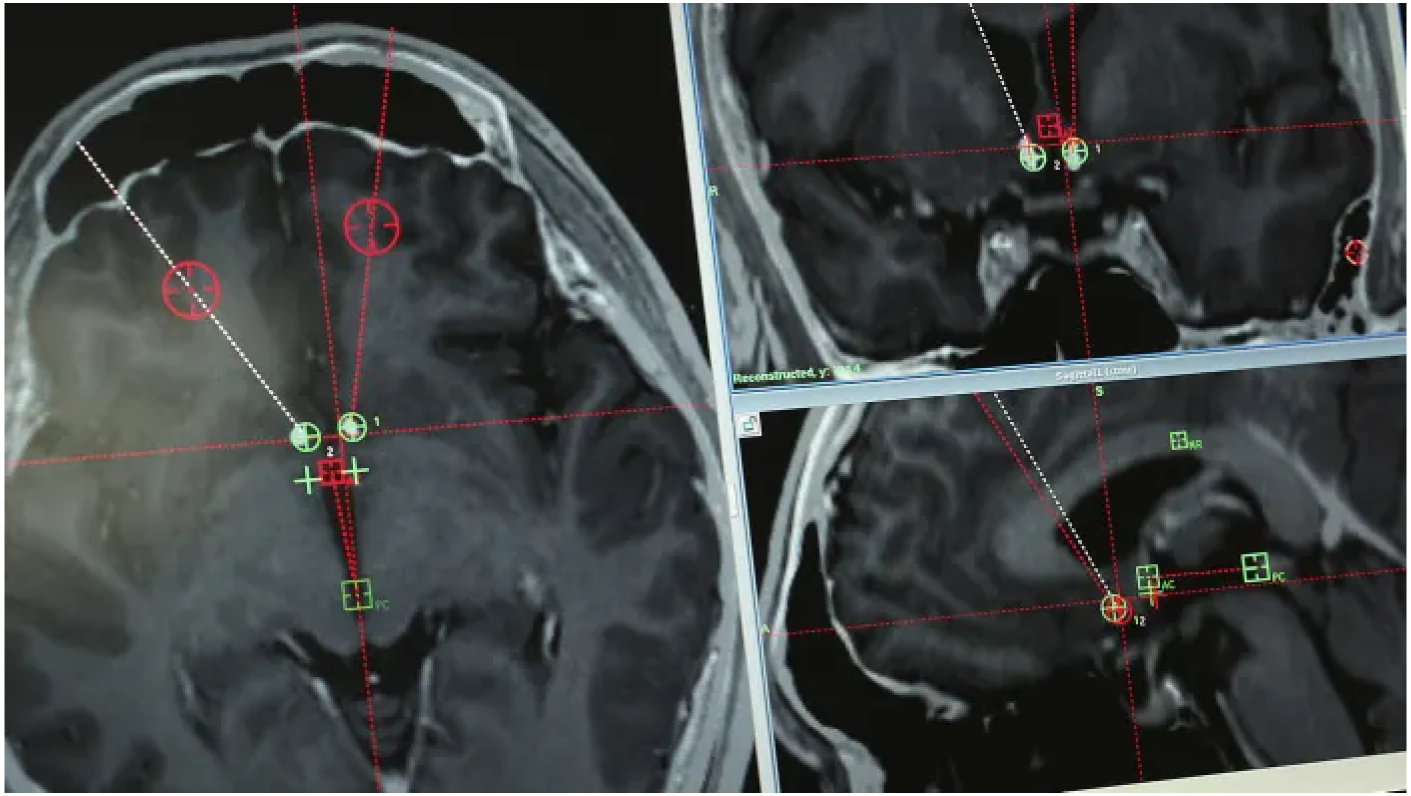
A robot used to implant threads seen next to two views of the needle it uses, which makes an incision just 2mm wide © Reuters

In contrast to neural implants, non-invasive neurotechnology uses techniques such as electroencephalography and magnetic resonance imaging to record the electrical or chemical activity of millions of neurons at the same time. The data can be used for medical diagnosis and neuroscience research or to control a computer. While it lacks the precision of stimulating or recording from individual neurons, removing the need for surgery within the skull greatly increases the potential market.

Proponents of non-invasive neurotech, such as Mr Reardon of CTRL-Labs, see huge scope in extracting more information from signals outside the brain. "Neuralink's announcement is focused on getting the signal [but] the really hard part is decoding the signals," he says. "Decoding the output is the mother of all machine learning problems."

Prof Coyle and his colleagues in Ireland have just completed a clinical trial showing that an EEG-based interface can tell whether someone with severe brain damage, who appears to be permanently unconscious, retains some capacity for conscious thought. The technique detects characteristic signs of neural activity as patients are asked to imagine moving a part of their body or answer questions about their personal background.

The US Defence Advanced Research Projects Agency has long been interested in neurotechnology for military purposes. Darpa announced in May that six organisations will be funded by its neurotechnology programme "to develop high-resolution, bidirectional brain-machine interfaces for use by able-bodied service members".



Chinese scientists put implants in the brain of a drug user in an attempt to control addiction at a hospital in Shanghai last year © AP

“Darpa is preparing for a future in which a combination of unmanned systems, artificial intelligence and cyber operations may cause conflicts to play out on timelines that are too short for humans to effectively manage with current technology alone,” says Al Emondi, the programme manager. By creating devices that do not require surgery, “Darpa could deliver tools that allow mission commanders to remain meaningfully involved in dynamic operations that unfold at rapid speed.” In other words, they would augment soldiers’ brainpower.

“The technology we are creating might ultimately help identify regions in the brain that are impacted by disease with a much higher resolution than previously possible,” says Jana Kainerstorfer, a researcher at Carnegie Mellon, which has a grant from Darpa to develop devices worn on the scalp that would send signals to and from the brain.

Whether the motivation for building brain-computer interfaces is military, medical, recreational or to communicate with AI, observers believe Mr Musk's entry will boost the whole field.

"He's heard forever that a private company could never send rockets to space. He was told nobody would ever buy an electric car," says Gil Luria, head of research at investment bank DA Davidson. "He thrives on the naysayers."

Cyborgs may not be coming at the pace predicted by Mr Musk — but it would be unwise to dismiss their eventual arrival as science fantasy.