Gravity sounds the alarm bell

A new device could potentially detect earthquakes more accurately and alert areas at risk faster

The aftermath of the earthquake and tsunami that hit Indonesia last year

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Storms, blizzards, floods, forest fires, deserts, tidal waves are examples where nature's forces leave humans powerless and terrified. The earthquake, no less devastating, dwarfs the others because it strikes without warning.

Masaya Kimura, Nobuki Kame, Shingo Watada, Makiko Ohtani, Akito Araya, Yuichi Imanishi, Masaki Ando and Takashi Kunugi, from the University of Tokyo, the National Institute of Advanced Industrial Science and Technology and the National Research Institute for Earth Science and Disaster Resilience, Tsukuba, Japan, announce in the journal, *Earth, Planets and Space*, that they have identified a feature of earthquakes that allows a substantially early warning before the earth actually quakes at a place.

Earthquakes arise from realignments in the earth's crust when pressure between adjoining plates, which builds up, is suddenly released. The realignment rapidly moves from the place where it starts, down to the end of the fault, and huge energy is released. The high speed movement of great masses sets off waves of compression and shear, which pass through the surrounding rock and earth, in all directions, downwards and horizontally. The compression waves, which are like sound waves moving through land or water, travel the fastest, but the shear waves and surface waves, which cause the ground to move, result in most of the damage.

It is estimated that there are 500,000 detectable earthquakes in the world each year, of which 100,000 can be felt, and 100 that cause damage. While there are instances of such events occurring very close to populated areas, most of them take place in desert regions or at the bottom of the sea. A major event, however, can cause devastation hundreds of kilometres away, not only destroying buildings and highways, but leading to fires, accidents, gas leaks and explosions. And then there's the damage caused by tsunamis.

All earthquakes are now detected and recorded by sensitive instruments installed in most parts of the world. The instruments first detect the compression wave and then shear wave. The difference in time reveals the distance, and readings that are taken at more than one station can fix the location. With many recording stations over an area, the detection can trigger a warning for places that are more distant. As the shear waves travel about seven km in a second, the warning can come a few seconds before the tremor reaches. Even this degree of warning can be useful to save lives. There are arrangements to set off city-wide sirens, for instance, and even automated opening of the doors of fire stations before the earthquake disables them.

For all this, the warning is not early enough, as even the compression wave moves at only about twice the speed of the shear wave, and it takes time for the signal to reach the sensors. And tsunamis, which originate in the sea, would come without warning.

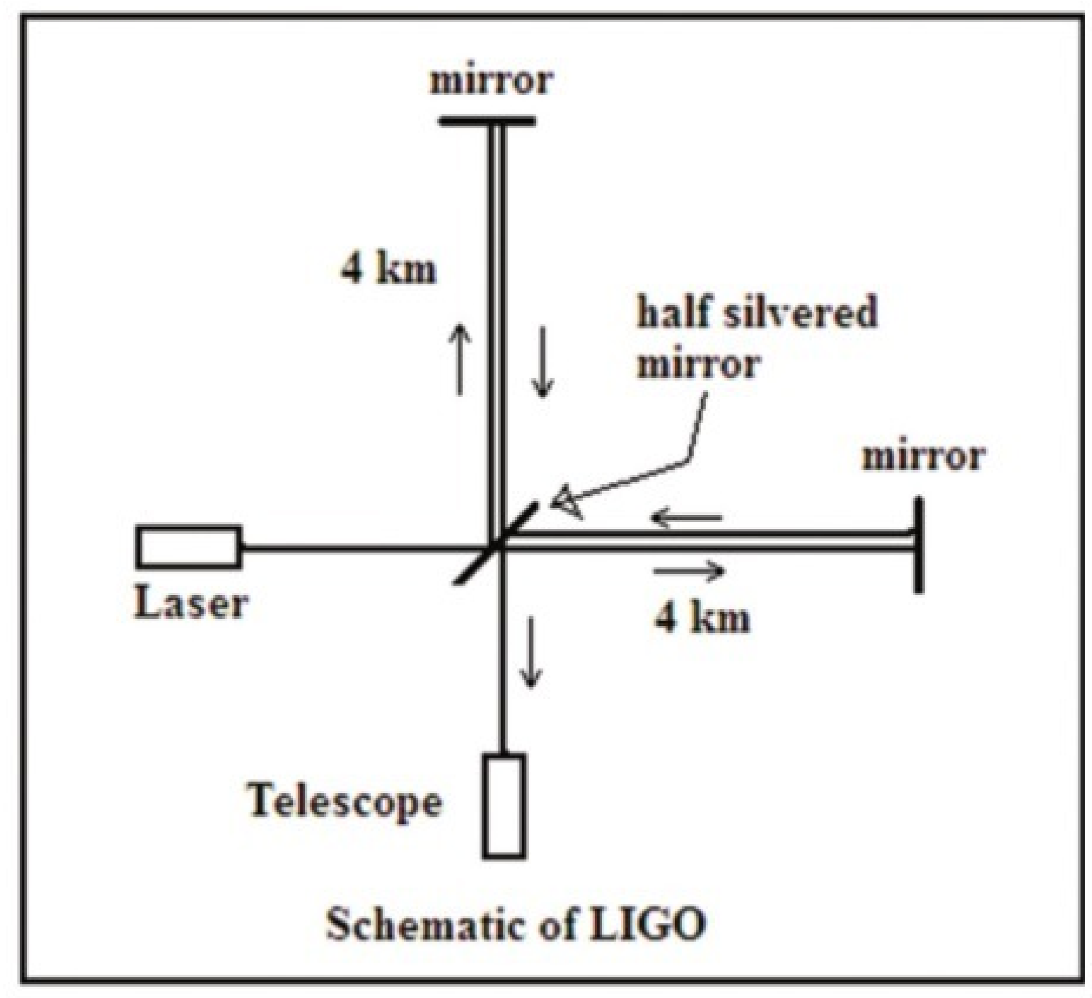
The warning hence needs to come sooner, which would be possible if the seismic event itself sent out the signal with effectively instantaneous speed. This is just what the team in Japan has announced — detecting gravity waves, which radiate at the speed of light, when there is very energetic displacement of huge masses of material.

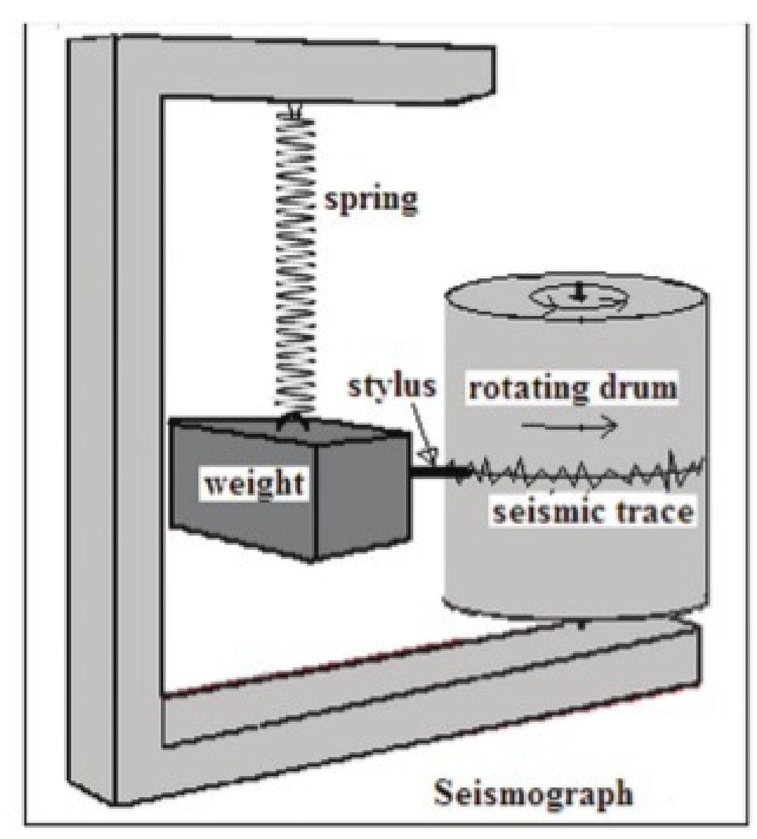
Einstein's General Theory of Relativity makes a prediction that the acceleration of masses, in the same way as acceleration of electric charges, should lead to emission of energy in the form of waves. In the case of moving electric charges, such as alternating currents in an antenna, the result is electromagnetic waves. This is readily understood, as electric currents lead to magnetic effects, which in turn create electric fields, and so on. The Theory of Relativity treats the force of gravity as the result of curvature that the presence of mass induces in the fabric of space. This conjecture, which arises from gravity being indistinguishable from acceleration, and the equivalence of mass and energy, has been tested and proved at the astronomical scale. Acceleration of masses, then, the theory shows, would create ripples in space, in the form of instantaneous changes in the distance between the points past which the disturbance propagates.

The team writing in *Earth, Planets and Space* refers to work in the last few years where the possibility of detecting such waves, which arise from the sudden redistribution of mass that happens in seismic events, has been examined. The T?hoku earthquake of 2011, off the east coast of Japan, was the most powerful earthquake recorded in Japan and the fourth most powerful recorded in the world. By 2011, there were a large number of different kinds of seismic recording stations in place in most of the world, and certainly in Japan. What got collected was hence really comprehensive, real time data of all kinds of signals, of vibration of the earth, as well as gravitational effects, before, during and after the earthquake.

The instruments to measure the very feeble effects of distant earthquakes usually rely on a heavy weight, suspended by a spring, or now, in a magnetic field maintained by superconducting coils, which responds with great sensitivity to vibrations of the casing of the arrangement. Naturally, arrangements of such sensitivity are beset by unwanted disturbances, and the data needs to be statistically examined to separate the meaningful signals from the "noise".

During analysis of the data of the 2011 earthquake, the paper says, "... nearly all the single-channel waveforms did not show any signals beyond the noise level except for several outliers." The researchers hence used another method, of putting together the data of selected seismometers, to create a "stacked" data set. The stacked data, the paper says, "showed a clear signal in the vertical component," albeit a weak signal, just a quarter of a billionth of the acceleration due to gravity of the Earth, "at an average distance of 987 km".





That the signal detected is feeble, the paper says, is possibly because the gravitational effects on the weight in the instruments are matched by acceleration of the ground on which they stand. A different method of detecting the effect, one which has been used to detect gravity waves that were expected to be generated by collapsing black holes at astronomical distances, would be more effective.

The method used for cosmological research is the Laser Interferometer Gravitational-Wave Observatory (Ligo), which has a pair of four-km tubes, which light beams traverse and serve to detect changes in the length of the path. A similar device, the Torsion Bar Antenna (Toba), consists of a pair of thin, hollow bars suspended as a cross. The bars have mirrors at either end and laser beams can monitor very small changes in length along one axis.

This device would be orders of magnitude more sensitive than the existing arrangements and, now that the existence of gravity waves from seismic events has been confirmed, it may serve as a means to detect the events a tiny fraction of a second after they commence, and alert areas that are at risk with much greater speed than is possible so far.

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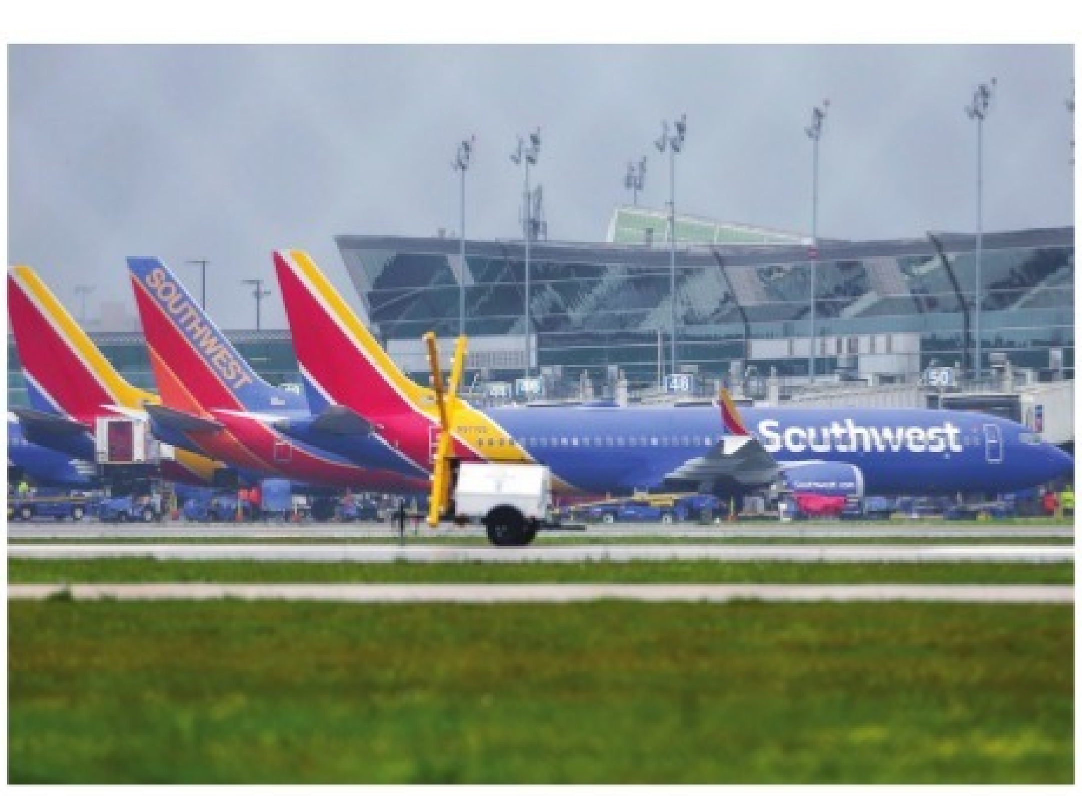
What brought about its doom

Flight data suggests faulty automated control systems caused the crash in Ethiopia



All Boeing 737 Max aircraft have been grounded across the globe

TIMOTHY TAKAHASHI

Emerging evidence from the recent crash in Ethiopia suggests that malfunctioning automatic control systems overwhelmed the crew and doomed the flight. Based on my analysis, it appears that the Ethiopian Airlines crew followed the standard procedures found in the Boeing 737 pilots operating handbook and flight crew operations manual.

A typical flight starts with manual control of the plane. The pilot and copilot will personally steer the aircraft onto the taxiway, configure the flaps for takeoff, actively control the aircraft as it accelerates down the runway, and smoothly pull back on the control yoke to lift the plane off the ground and into flight. The flight's altitude and speed data, transmitted from the plane in real time and made available to the public by *FlightRadar24.com*, shows that happened normally as Ethiopian Airlines Flight 302 left the runway.

Everything appears to have gone as usual on the initial climb away from the takeoff, too. Normally, the pilot will retract the landing gear and maintain a relatively steady speed as the aircraft climbs. The plane might accelerate slightly until it's going fast enough that the flaps — extended to increase lift at lower speeds — can be safely retracted, letting the wings themselves generate the necessary lift. This process usually takes place in the first minute after takeoff. Once the aircraft has climbed to 1,000 feet above the ground, the pilot will engage the autopilot system.

That's the point at which the computer takes over — and where, my analysis of the data suggests, things went wrong for Ethiopian Airlines Flight 302. A modern autopilot system gives the computer command of the engine throttles, rudder, elevators and ailerons — basically full control over the aircraft.

Simulating the expected flight

Using modelling tools developed by my research team, I recreated a hypothetical flight profile to simulate the Ethiopian Airlines 737 departure based on the handbook procedure for an identical plane carrying a similar amount of weight. The simulation timing, key speeds and altitudes all follow my best estimate of the procedure that a trained pilot would be expected to follow.

Comparing this data to the actual flight data, I was able to see where the ideal predicted performance differs from the actual motions of the lost flight. My simulation closely matches the actual speeds of the aircraft on its takeoff roll, and recreates its first few miles of airborne flight. The pilot let the aircraft accelerate gently during initial climb, which isn't specifically called for or prohibited in the official manual.

The flight paths between a typical flight and the actual course sharply diverge only after the aircraft reached an altitude of 1,000 feet above the runway. Immediately after flap retraction, the pilot should have engaged the autopilot, leaving the computer to command a climb at constant airspeed. Instead, the ill-fated flight began to dive and accelerate, losing altitude and gaining speed until it struck the ground a few miles away from the airport.

There are several possible reasons a plane could crash like this. One is that an engine could malfunction. But the telemetry data doesn't indicate the loss of acceleration that an engine failure would cause. Another reason could be that some part of the fuselage, wings or tail broke or collapsed. The data doesn't show the sort of change in speed or climb rate that would result from such a loss of stability.

The crash does not appear to be due to pilot error, either. I've studied pilot overreactions during developing emergencies, and see no evidence of that before the initial dive; the pilots seem to fly an otherwise typical takeoff. If there was some other mechanical failure, the pilots didn't report it to the control tower. There is no indication that they overreacted or overcompensated to some emergency — the radar track shows no evidence of a condition called "wallowing," characterised by periodic fluctuations in speed and altitude, nor any accidental stall, where airspeed drops sharply before the plane loses altitude.

Therefore, it appears that the various automatic control systems conspired to prevent the pilots from asserting direct control over the ailerons, elevators and rudder that keep the aircraft aloft and on course.

How long on the ground?

More than 300 Boeing 737 Max aircraft have been flying since 2017, with thousands of safe takeoffs and landings. That suggests the problem for Ethiopian Airlines — and possibly the 2018 Lion Air crash too — is one of the difficult sort of engineering troubles that happen intermittently, or even seemingly randomly, in very complex systems.

Boeing has already said it will update the aircraft's software. Any fixes will have to be checked not only to ensure that they handle whatever the exact problem is that's identified by crash investigators, but also to make sure they don't cause other unexpected errors. That will take its own amount of time. In the meantime, all the Boeing 737 Max aircraft in the world are on the ground, waiting.

The writer is professor of practice for aerospace engineering, Arizona State University, US. This article first appeared on www.theconversation.com

PLUS POINTS

Lethal blood

A drug, which poisons mosquitoes when they feed on it, could provide a powerful new avenue for tackling malaria. Trials showed it reduced cases among children in rural Burkina Faso by 20 per cent.

Treating adults and children with the drug ivermectin helped to control the spread of malaria without causing harmful side-effects, the research led by a team at the Colorado State University found. They concluded that the new approach in combination with drugs to tackle the infections could slow down the creature's ability to resist the disease.

Currently, conventional insecticides and anti-malarials are hampering the eradication effort. "Ivermectin reduces new cases of malaria by making a person's blood lethal to the mosquitoes that bite them, killing mosquitoes and therefore reducing the likelihood of infection of others," said Brian Foy, author of the study published in *The Lancet*. Malaria's life cycle is split between humans and its host mosquitoes, the parasite is passed into the blood with a bite where it matures and multiplies and then waits to be transmitted on to the next mosquito to reproduce.

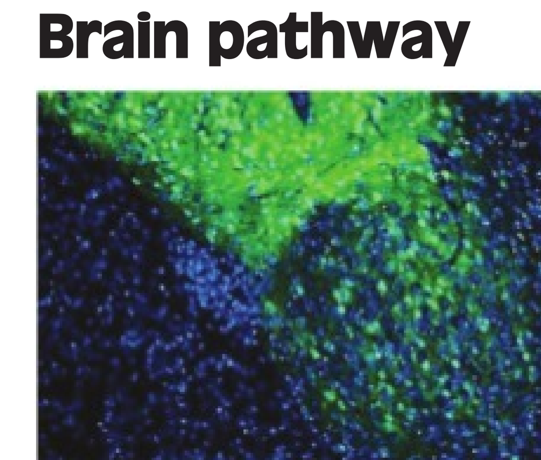
Ivermectin is already used to treat other parasites causing river blindness and scabies, but its effects on malaria transmission haven't been studied in a large trial. For the 18-week study researchers recruited 2,700 people, including 590 children, across eight villages with half in the treatment group receiving a dose of ivermectin every three weeks.

Regular visits from nurses were used to assess children for malaria symptoms and confirmed with a blood test and it found twice as many children in the treatment group had no malaria attacks. In all there were an average of two malaria attacks per child in the treatment group compared to 2.49 in the control villages, without any additional harmful side effects. If the findings are replicated in larger studies ivermectin's unique way of working could help reduce the burden of malaria and control mosquito populations.

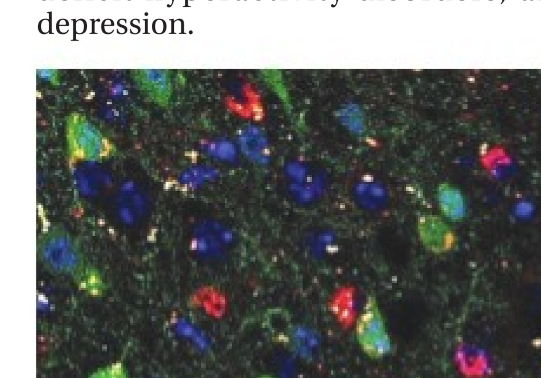
Professor Chris Drakeley from the London School of Hygiene and Tropical Medicine, who was not involved in the research, said that the looming resistance crisis means new approaches are "desperately needed". He said the current study is "proof of principle" that ivermectin can reduce episodes of malaria and showed a significant reduction in episodes with no safety issues. "This study is the first of its kind to demonstrate effect at community level, highlighting a potential new avenue for malaria control," he added.

The independent

Brain pathway



This is what impulsivity looks like. Researchers from Singapore and South Korea have uncovered new details of a brain pathway that can cause impulsive behaviours. Using mice, the team led by professor George Augustine of Nanyang Technological University's Lee Kong Chian School of Medicine found that impulsive behaviour is triggered when dopamine signals in the brain are passed to an unexpected area of it. It usually happens in behaviours like binge eating and impulsive shopping. The work done with researchers from Korea University and the Korea Institute of Science and Technology could pave the way for treatment options for neuropsychiatric disorders like bipolar, attention deficit hyperactivity disorders, and depression.



The green dye shows neurons in the central amygdala that express special dopamine receptors, which are important for impulsive behaviour. The image (above) zooms in and highlights how green neurons interact with red ones, forming the pathway that triggers impulsive behaviour.

The strait times/ann