

▶ and US space programmes — their successes and failures. This political, cultural and technical context is enriched with information that has come from the cosmonauts themselves in recent years. For example, details of the accidents and deaths that hindered the Soviet lunar programme, from the cosmonauts' point of view, enable Eicher to tell a more complete story. He strikes a fine balance between detail and readability.

But the book is so much more. Its 150 stereo photographs, which can be seen in 3D through a stereo viewer, make it an immersive experience. Since childhood, May has collected stereoscopic devices — a Victorian technology in which two photographs of the same subject (taken a small horizontal distance apart) are displayed side by side. Looking at these through a viewing device, at a certain distance and with eyes 'relaxed', the brain creates the perception of depth, and previously unresolved details jump into focus. The pairs of images that Eicher and May include show everything from cosmonaut Alexei Leonov, the first spacewalker, in 1965, to the *Apollo 12* lunar module *Intrepid* flying insect-like above the Moon's surface in 1969. A hand-held LITE OWL viewer developed by May is included with the book with instructions (see [go.nature.com/2ezgyg6](http://go.nature.com/2ezgyg6)). For those struggling to see in 3D, try starting with high-contrast images such as the one of Comet 67P/Churyumov-Gerasimenko.

Stereo photography was not an aim of the Apollo missions. But many sequential photographs were taken — for instance by Stuart Roosa in *Apollo 14* while circling the Moon — which enabled May to assemble several pairs. May and his team also trawled the NASA archives to find serendipitous pairs of photographs or film stills with just the right baseline separation. To illustrate the



A stereoscopic image of US astronaut Gene Cernan next to a lunar rover during an Apollo 17 moonwalk.

Soviet effort, for which no sequential images existed, they had to convert 'mono' photographs into stereo pairs.

As these vivid images remind us, the pace of progress would have been much slower without the fierce competitiveness of the space race. However, the cold-war wall between the two countries made avoidable, sometimes tragic, mistakes inevitable. One chilling example is the *Apollo 1* accident in 1967. During a routine countdown rehearsal, a fire erupted in the craft's main capsule, which contained pure oxygen; astronauts Roger Chaffee, Gus Grissom and Ed White died almost instantly. (Only later was a quick-release hatch added to the design.) Six years before, unbeknown to NASA, trainee cosmonaut Valentin Bondarenko had suffered a similar fate during a test in Moscow. The two superpowers' first cooperative spaceflight would have to wait until 1975.

*Mission Moon 3-D* devotes significant



space to the ultimate sacrifice made by humans (and animals) in the name of space exploration, underlining the risks of propelling earthlings into an alien environment. Now, NASA, the Russian, Japanese and Chinese space agencies, and the private companies SpaceX and Blue Origin, plan to send humans back to the Moon. Before that happens, any benefits must be weighed carefully against the risks, and the expense. Reaching Mars will demand that several nations work together, with involvement from the public and private sectors. Robotic and telescopic missions cost much less and can reach more-distant planets and moons. But there is no substitute for human experience; and while we wait for another foot to fall on an extraterrestrial landscape, books such as this one give us an inkling of that ultimate thrill. ■

May Chiao is chief editor of *Nature Astronomy*.

## TECHNOLOGY

## The *Doctor Who* theme and beyond: female pioneers of electronic music

Joanne Baker lauds a paean to the experimentalists of the BBC Radiophonic Workshop.

The history of electronic music usually centres on the men (including Pierre Schaeffer, Olivier Messiaen, Pierre Boulez, Karlheinz Stockhausen and Edgard Varèse) who developed *musique concrète* from recorded everyday sounds in Paris in the mid-twentieth century. Also in those decades, a group of sound engineers — many of them women — were making waves in an old London skating rink.

The BBC Radiophonic Workshop

### Synth Remix

93 Feet East, London.  
8 November 2018; Touring 8–11 November.

produced effects and theme tunes for the British broadcaster, including iconic sounds for the sci-fi television and radio programmes *Doctor Who* and *The Hitchhiker's Guide to the Galaxy*, using electronic oscillators and tape loops decades before synthesizers were common. That many of

its engineers were women was, and still is, a rarity. Last week, two of them, Daphne Oram and Delia Derbyshire, were celebrated anew in Synth Remix, a concert series of live performances and DJ sets touring Britain.

Oram (1925–2003) co-founded the Radiophonic Workshop. She gained experience in mixing electronics and music during the Second World War while working for the BBC on sound balance for radio broadcasts. During Germany's bombings of London in

the Blitz, she switched pre-recorded tracks of orchestral music into broadcasts of live music. That allowed the musicians to flee the city's grand concert venue, the Albert Hall, without the radio audience knowing.

In the 1950s, Oram became intrigued by the potential of tape recording to transform music by exploding space and time. She was a fan of *musique concrète*, regularly staying up all night to mix her own tracks. In 1958, after years of badgering the BBC to modernize its music, Oram and her colleague Desmond Briscoe were given a room with some old equipment. Thus began the workshop.

Oram left after just a year. The BBC asked her to take six months off, saying it was concerned that the equipment might have adverse effects on the human body. So she quit.

Oram set up her own home studio in a converted rural oast house in Kent. She continued to compose electronic sounds, and to lecture and write about the nature of vibrations. She launched a field that she called Oramics, using a device that she built for 'drawing' sound. The size of a dressing table, it subverted the technology behind the cathode-ray oscilloscope, which converts sound waves into a picture. Lines, squiggles and dots sketched on 35-mm film were scanned and used as indications of pitch, vibrato and timbre. (It was, in effect, an early sequencer — a technology that eventually came along in the 1980s.) In her seminal 1972 book *An Individual Note of Music, Sound and Electronics*, she wrote of humans as instruments, harbouring "a whole spectrum of resonant frequencies" that are "vibrant with pulsating tension".

Oram paved the way for Derbyshire (1937–2001), who famously crafted the unearthly 'sweeps and swoops' of the *Doctor Who* theme

tune in 1963. Derbyshire told interviewers that her love of abstract sounds came from the air-raid sirens she heard growing up in Coventry during the Blitz, recalling that "the sound of the 'all clear'" was electronic music. She studied mathematics and music at the University of Cambridge, and took an analytical approach to experimenting with sound. Her notes, now archived at the University of Manchester, are full of mathematical symbols and equations. She jotted down explicit frequencies and used the dots and dashes of Morse code.

Her sketched scores are visual — crescendos of squiggles, rings of organic contours and hatched textures of mass and void. Triangular bursts march across the page like streams from flak guns. Some rounded forms look like the Lissajous patterns (formed from interacting sine waves) that she must have seen on oscilloscope displays.

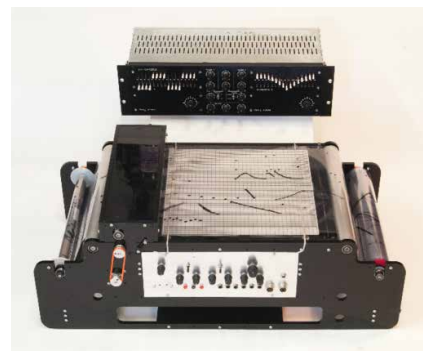
**"Her sketched scores are visual — crescendos of squiggles, rings of organic contours and hatched textures of mass and void."**

Her notes are also littered with evocative words: hum, beat, splash, shimmer.

This Radio-phonetic legacy was the launching point for the concerts, performed by musician Jo Thomas and artist

Olivia Louvel. At the first performance at 93 Feet East, a concrete venue in east London, each deftly controlled networks of tabletop electronics. These sent tsunamis of sound waves shuddering through the audience's chests, and lofted clouds of siren vocals around our heads. The compositions were compelling, richly textured and darkly powerful.

Electronic music integrates science with



An Oramics machine for drawing sound.

art, and Thomas has roamed far into that liminal space. In 2012, her *Crystal Sounds of a Synchrotron* — based on blips and beeps from the Diamond Light Source particle accelerator near Didcot, UK — won an international award for digital music and sound art from Austrian arts body Ars Electronica. Here, her three-part work *Nature's Numbers* nods to Derbyshire and Oram using a bank of self-built electronic components, conventional synthesizers and computers augmented with tones of her own voice. Thomas immersed herself in Derbyshire's archives for Synth Remix.

'Time Lament', the first part of Thomas's performance, combines high, plaintive vocals over a heartbeat reminiscent of spinning tape loops. Inspirations include Derbyshire's love of seventeenth-century composer Henry Purcell (and his aria 'Dido's Lament') and effects from *The Hitchhiker's Guide to the Galaxy*. In 'Echoes of the Earth', sounds like showers of rain punctuate the eerie silence of a cavern, as a homage to Derbyshire's vocal experimentations. 'Cellophane Resonance' is a playful collage of sci-fi sound effects. Here, Thomas exploits a compact reproduction of an Oramics machine, generating sounds from scribbles on what look like rolls of transparent film from an overhead projector.

Louvel's multimedia suite *Data Regina* liberates the voice of another woman from the past. Tudor monarch Mary, Queen of Scots — ultimately executed by her cousin, Elizabeth I of England — was a prolific writer and poet. Yet few know her works. Louvel's voice, computer music and a video backdrop of avatars that look like chess pieces transmit the story of the tortured queen. The result is a soaring, gut-wrenching opera.

These intuitive and democratic takes on compositions by Oram and Derbyshire reverberate today. You don't need a bank of high-powered electronics to pick out a beat or strike a chord. Go on, grab your laptop, switch on an app and play with sound. This, in essence, is what they did. ■

**Joanne Baker**, a senior Comment editor at *Nature in London*, has written three books about physics.



Daphne Oram in her home studio in 1962.