

► theories of Einstein and de Broglie and turned them into a fully fledged interpretation capable of shaking up the status quo. David Bohm argued that particles in quantum systems existed whether observed or not, and that they have predictable positions and motions determined by pilot waves. John Bell then showed that Einstein's concerns about locality and incompleteness in the Copenhagen interpretation were valid. It was he who refuted von Neumann's proof by revealing that it ruled out only a narrow class of hidden-variables theories.

The scientific community greeted Bohm's ideas coolly. A former mentor, J. Robert Oppenheimer, said: "if we cannot disprove Bohm, then we must agree to ignore him". And, as Becker shows, Bohm's leftist views led to an appearance before the House Un-American Activities Committee, and subsequent ostracization.

Bohm's contemporary, physicist Hugh Everett, delivered another challenge to the Copenhagen interpretation. In 1957, Everett set out to resolve the 'measurement problem' in quantum theory — the contradiction between the probabilistic nature of particles at the quantum level and their 'collapse', when measured, into one state at the macroscopic level.

Everett's many-worlds interpretation posited no collapse. Instead, probabilities bifurcate at the moment of measurement into parallel universes — such as one in which Schrödinger's cat is alive and another in which it's dead. Although an infinite number of untestable universes seems unscientific to some, many physicists today view the theory as important.

The book has a few minor shortcomings. Becker gives too much space to recent applications building on Bell's research, and too little to new developments in the philosophy of science. Yet he, like cosmologist Sean Carroll in his 2016 *The Big Picture* (R. P. Crease *Nature* 533, 34; 2016), does make an explicit case for the importance of philosophy. That's a key call, with influential scientists such as Neil deGrasse Tyson dismissing the discipline as a waste of time.

What Is Real? is an argument for keeping an open mind. Becker reminds us that we need humility as we investigate the myriad interpretations and narratives that explain the same data. ■

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"Becker reminds us that we need humility as we investigate the myriad interpretations that explain the same data."



A Pan Am shuttle prepares to dock at the international Space Station V in this classic scene from the film.

IN RETROSPECT

2001: A Space Odyssey

Fifty years on, the masterful science-fiction film looks more prophetic than ever, reflects **Piers Bizony**.

In 1968, film-maker Stanley Kubrick and his screenwriting colleague, science-fiction author Arthur C. Clarke, presented *2001: A Space Odyssey*. Half a century later, this unprecedentedly detailed speculation about our place in the cosmos and our evolving relationship with technology is regarded as one of the great landmarks in cinema.

The influence of *2001* on the design of subsequent space-film hardware and special effects has been pervasive. However, in terms of artistic and philosophical bravura, it has been a harder act to follow. In 2007, director Ridley Scott (of *Blade Runner* and *Alien* fame) told a Venice Film

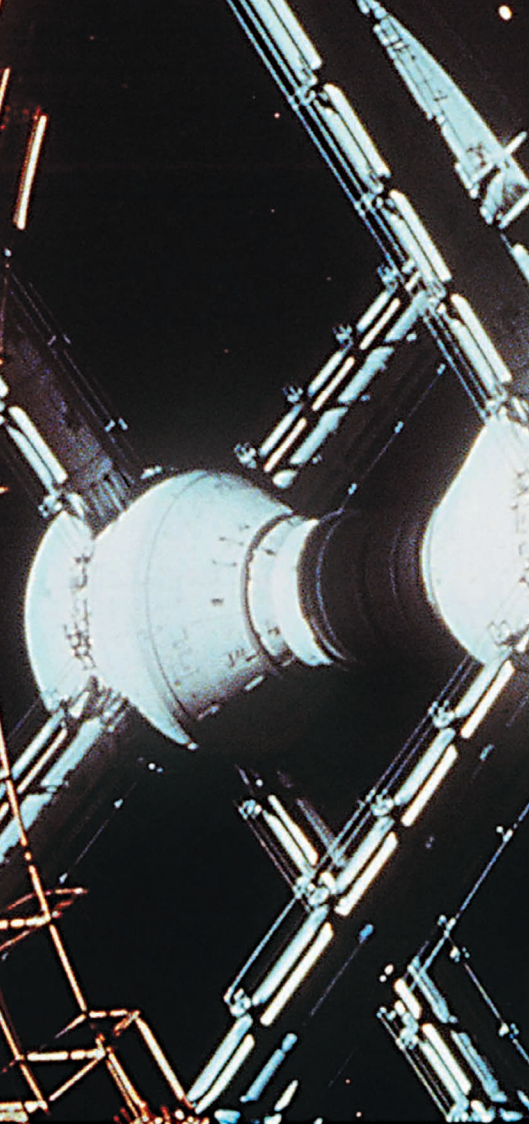
2001: A Space Odyssey

DIRECTOR: STANLEY KUBRICK; CO-WRITER: ARTHUR C. CLARKE
Metro-Goldwyn-Mayer: 1968.

Festival audience: "After *2001*, science fiction is dead."

The narrative was ambitious, to say the least. Prehistoric apemen have a mind-altering encounter with an alien black monolith. Four million years later, a giant spacecraft is sent to Jupiter on a mysterious mission. On board are two astronauts, three hibernating scientists and a seemingly sentient computer, HAL 9000. Hovering above Jupiter, another monolith waits.

Monoliths aside, *2001* was prescient in almost all its detailed predictions of



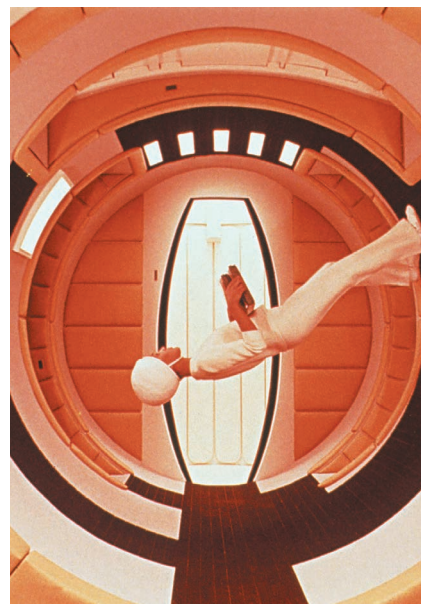
companions on board the Jupiter-bound spaceship. As our machines smarten up, we will dumb down, Kubrick suggested. The crass human discourse often found on today's algorithmically clever social-media platforms seems to bear out his pessimism.

Certainly, in the film, the surviving astronaut's final conflict with HAL prefigures a critical problem with today's artificial-intelligence (AI) systems. How do we optimize them to deliver good outcomes? HAL thinks that the mission to Jupiter is more important than the safety of the spaceship's crew. Why did no one program that idea out of him? Now, we face similar questions about the automated editorship of our searches and news feeds, and the increasing presence of AI inside semi-autonomous weapons.

We also face the startling fact that 1960s assumptions about the progress of AI were optimistic (computing pioneer Marvin Minsky served as a consultant for *2001*). No machine available today can match HAL's performance. Just look at the YouTube spoofs of "digital personal assistants" reimagined as HAL: Kubrick's red-eyed genius outsmarts them all.

Where the film made technical errors, it did so in ways that were flawed rather than merely wrong. Kubrick's machinery is a matter for nerdy analysis instead of the ridicule usually reserved for outdated fantasies. Rocket experts happily argue about the film's docking arrangements and control-panel layouts; but none of the machinery is out of bounds in terms of what we could actually achieve.

And Kubrick and Clarke confidently predicted space projects that still lie many years, or decades ahead, 17 years after the film's eponymous dateline. Famously,



A shuttle flight attendant walks in zero gravity.

Kubrick gave us the most persuasive space station in all of science fiction, a gigantic twin-wheeled "Orbiter Hilton". It was complete with coffee-vending machines, garish designer chairs in the lounges, phone booths accepting credit cards, and panoramic windows offering spectacular views of the Earth (something so familiar to the film's spacefarers that they ignore it).

Space planners of the 1960s assumed that artificial gravity would be essential. In the event, the International Space Station was designed for science experiments that depend on cancelling out gravity's influence, not replicating it. Now the wheel has turned full circle, as we recognize the debilitating effects of long-term weightlessness on the human body. Aerospace engineers are starting to think about how we could make revolving habitats for future deep-space missions, or orbiting hotels for private adventurers.

As for such doughty explorers, recent triumphs of Elon Musk's SpaceX rocket company validate Kubrick's use of Pan Am as his space-shuttle carrier of choice. Although Pan Am no longer exists, the corporate conquest of the cosmos is under way, just as *2001* predicted. For today's orbital entrepreneurs, the film is not just a beautiful piece of science fiction. It is a technical manifesto — an inspirational call to arms, around which a real commercial space industry is being founded.

Of course, *2001* also suggests some kind of non-terrestrial influence over human progress. After unsatisfactory experiments trying to depict aliens, Kubrick chose only to hint at their presence, allowing those black slabs to stand in for — well, for what, exactly?

Today, we know that planetary systems orbiting other suns are the rule rather than the exception, and that prebiotic molecules suffuse the vast, interstellar clouds of dust and gas from which new stars and planets are born. Have any of these molecules sparked into life on other worlds, perhaps giving rise to intelligent entities? If so, might some of them be more advanced than we are?

Should we watch out for superior "aliens" closer to home, and guard against AI systems one day supplanting us in the evolutionary story yet to unfold? Or does the absence of anything like HAL, even after 50 years, suggest that there is, after all, something fundamental about intelligence that is impossible to replicate inside a machine? Until we know the answers to such profound questions, *2001: A Space Odyssey* cannot stale. ■

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twenty-first-century technology. For instance, in August 2011, the Samsung electronics group began a defence against a claim of patent infringement by Apple. Who invented the tablet computer? Apple claimed unique status for its iPad; Samsung presented a frame from *2001*.

Samsung noted that the design claimed by Apple had many features in common with that of the tablet shown in the film clip — most notably, a rectangular shape with a display screen, narrow borders, a flat front and a thin form. In an era when computers still needed large rooms to accommodate them, Kubrick's special-effects team rigged hidden projectors to enliven devices that looked as though you could hold them in one hand. Only the need to trim the film's running length prevented ingenious mock-ups of touch-sensitive gaming screens and electronic newspapers from making the final cut.

Indeed, *2001* got much right about the twenty-first century, including the psychological costs of our reliance on technology. Kubrick's astronauts look listless inside vehicles perfectly capable of functioning without them. Dialogue in the film is deliberately banal. HAL gets all the best lines, even as he kills off most of his human