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INTRODUCTION

A COSMIC CAMEO:

Suppose aliens existed, and that some had been watching our planet for its entire forty-five million centuries, what would they have seen? Over most of that vast time-span, Earth's appearance altered very gradually. Continents drifted; ice cover waxed and waned; successive species emerged, evolved, and became extinct.

But in just a tiny sliver of Earth's history—the last hundred centuries—the patterns of vegetation altered much faster than before. This signalled the start of agriculture—and then urbanisation. The changes accelerated as human populations increased.

Then there were even faster changes. Within just fifty years the amount of carbon dioxide in the atmosphere began to rise abnormally fast. And something else unprecedented happened: rockets launched from the planet's surface escaped the

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biosphere completely. Some were propelled into orbits around the Earth; some journeyed to the Moon and other planets.

The hypothetical aliens would know that Earth would gradually heat up, facing doom in about six billion years when the Sun would flare up and die. But could they have predicted this sudden ‘fever’ halfway through its life—these human-induced alterations—seemingly occurring with runaway speed?

If they continued to keep watch, what would they witness in the next century? Will a final spasm be followed by silence? Or will the planet’s ecology stabilise? And will an armada of rockets launched from Earth spawn new oases of life elsewhere?

This book offers some hopes, fears, and conjectures about what lies ahead. Surviving this century, and sustaining the longer-term future of our ever more vulnerable world, depends on accelerating some technologies, but responsibly restraining others. The challenges to governance are huge and daunting. I offer a personal perspective—writing partly as a scientist (an astronomer) but also as an anxious member of the human race.

* * *

For medieval Europeans, the entire cosmology—from creation to apocalypse—spanned only a few thousand years. We now envision time-spans a million times longer. But even in this vastly extended perspective, this century is special. It is the first when one species, ours, is so empowered and dominant that it has the planet's future in its hands. We've entered an era that some geologists call the Anthropocene.

The ancients were bewildered and helpless in the face of floods and pestilences—and prone to irrational dread. Large parts of the Earth were terra incognita. The ancients' cosmos was just the Sun and planets surrounded by the fixed stars spread across the 'vault of heaven'. Today, we know our Sun is one of one hundred billion stars in our galaxy, which is itself one of at least one hundred billion other galaxies.

But despite these hugely stretched conceptual horizons—and despite our enhanced understanding of the natural world, and control over it—the timescale on which we can sensibly plan, or make confident forecasts, has become shorter rather than

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longer. Europe's Middle Ages were turbulent and uncertain times. But these times played out against a 'backdrop' that changed little from one generation to the next; devotedly, medieval masons added bricks to cathedrals that would take a century to finish. But for us, unlike for them, the next century will be drastically different from the present. There has been an explosive disjunction between the ever-shortening timescales of social and technical change and the billion-year time-spans of biology, geology, and cosmology.

Humans are now so numerous and have such a heavy collective 'footprint' that they have the ability to transform, or even ravage, the entire biosphere. The world's growing and more demanding population puts the natural environment under strain; peoples' actions could trigger dangerous climate change and mass extinctions if 'tipping points' are crossed—outcomes that would bequeath a depleted and impoverished world to future generations. But to reduce these risks, we don't need to put the brakes on technology; on the contrary, we need to enhance our understanding of nature and deploy appropriate technology more urgently. These are the themes of chapter 1 of this book.

Most people in the world live better lives than their parents did—and the proportion in abject poverty has been falling. These improvements, against a backdrop of a fast-growing population, couldn't have happened without advances in science and technology—which have been positive forces in the world. I argue in chapter 2 that our lives, our health, and our environment can benefit still more from further progress in biotech, cybertech, robotics, and AI. To that extent, I am a techno-optimist. But there is a potential downside. These advances expose our ever more interconnected world to new vulnerabilities. Even within the next decade or two, technology will disrupt working patterns, national economies, and international relations. In an era when we are all becoming interconnected, when the disadvantaged are aware of their predicament, and when migration is easy, it is hard to be optimistic about a peaceful world if a chasm persists, as deep as it is in today's geopolitics, between welfare levels and life chances in different regions. It is specially disquieting if advances in genetics and medicine that can enhance human lives are available to only a privileged few and portend more fundamental forms of inequality.

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There are some who promote a rosy view of the future, enthusing about improvements in our moral sensitivities as well as in our material progress. I don't share this perspective. There has plainly, thanks to technology, been a welcome improvement in most people's lives and life chances—in education, health, and lifespan. However, the gulf between the way the world is and the way it could be is wider than it ever was. The lives of medieval people may have been miserable, but there was little that could have been done to improve those lives. In contrast, the plight of the 'bottom billion' in today's world could be transformed by redistributing the wealth of the thousand richest people on the planet. Failure to respond to this humanitarian imperative, which nations have the power to remedy, surely casts doubt on any claims of institutional moral progress.

The potentials of biotech and the cyberworld are exhilarating—but they're frightening too. We are already, individually and collectively, so greatly empowered by accelerating innovation that we can—by design, or as unintended consequences—engender global changes that will resonate for centuries. The smartphone, the web, and their ancillaries are already crucial to our networked lives. But these

technologies would have seemed magical even just twenty years ago. So, looking several decades ahead we must keep our minds open, or at least ajar, to transformative advances that may today seem like science fiction.

We can't confidently forecast lifestyles, attitudes, social structures, or population sizes even a few decades hence—still less the geopolitical context against which these trends will play out. Moreover, we should be mindful of an unprecedented kind of change that could emerge within a few decades. Human beings themselves—their mentality and their physique—may become malleable through the deployment of genetic modification and cyborg technologies. This is a game changer. When we admire the literature and artefacts that have survived from antiquity, we feel an affinity, across a time gulf of thousands of years, with those ancient artists and their civilisations. But we can have zero confidence that the dominant intelligences a few centuries hence will have any emotional resonance with us—even though they may have an algorithmic understanding of how we behaved.

The twenty-first century is special for another reason: it is the first in which humans may develop

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habitats beyond the Earth. The pioneer ‘settlers’ on an alien world will need to adapt to a hostile environment—and they will be beyond the reach of terrestrial regulators. These adventurers could spearhead the transition from organic to electronic intelligence. This new incarnation of ‘life’, not requiring a planetary surface or atmosphere, could spread far beyond our solar system. Interstellar travel is not daunting to near-immortal electronic entities. If life is now unique to the Earth, this diaspora will be an event of cosmic significance. Yet if intelligence already pervades the cosmos, our progeny will merge with it. This would play out over astronomical timescales—not ‘mere’ centuries. Chapter 3 presents a perspective on these longer-term scenarios: whether robots will supersede ‘organic’ intelligence, and whether such intelligence already exists elsewhere in the cosmos.

What happens to our progeny, here on Earth and perhaps far beyond, will depend on technologies that we can barely conceive today. In future centuries (still an instant in the cosmic perspective), our creative intelligence could jump-start the transitions from an Earth-based to a space-faring species, and from biological to electronic intelligence—transitions

that could inaugurate billions of years of posthuman evolution. On the other hand, as discussed in chapters 1 and 2, humans could trigger bio, cyber, or environmental catastrophes that foreclose all such potentialities.

Chapter 4 offers some (perhaps self-indulgent) excursions into scientific themes—fundamental and philosophical—that raise questions about the extent of physical reality, and whether there are intrinsic limits to how much we'll ever understand of the real world's complexities. We need to assess what's credible, and what can be dismissed as science fiction, in order to forecast the impact of science on humanity's long-term prospects.

In the final chapter I address issues closer to the here and now. Science, optimally applied, could offer a bright future for the nine or ten billion people who will inhabit the Earth in 2050. But how can we maximise the chance of achieving this benign future while avoiding the dystopian downsides? Our civilisation is moulded by innovations that stem from scientific advances and the consequent deepening understanding of nature. Scientists will need to engage with the wider public and use their expertise beneficially, especially when the stakes

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will be immensely high. Finally, I address today's global challenges—emphasising that these may require new international institutions, informed and enabled by well-directed science, but also responsive to public opinion on politics and ethics.

Our planet, this 'pale blue dot' in the cosmos, is a special place. It may be a unique place. And we are its stewards in an especially crucial era. That is an important message for all of us—and the theme of this book.

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