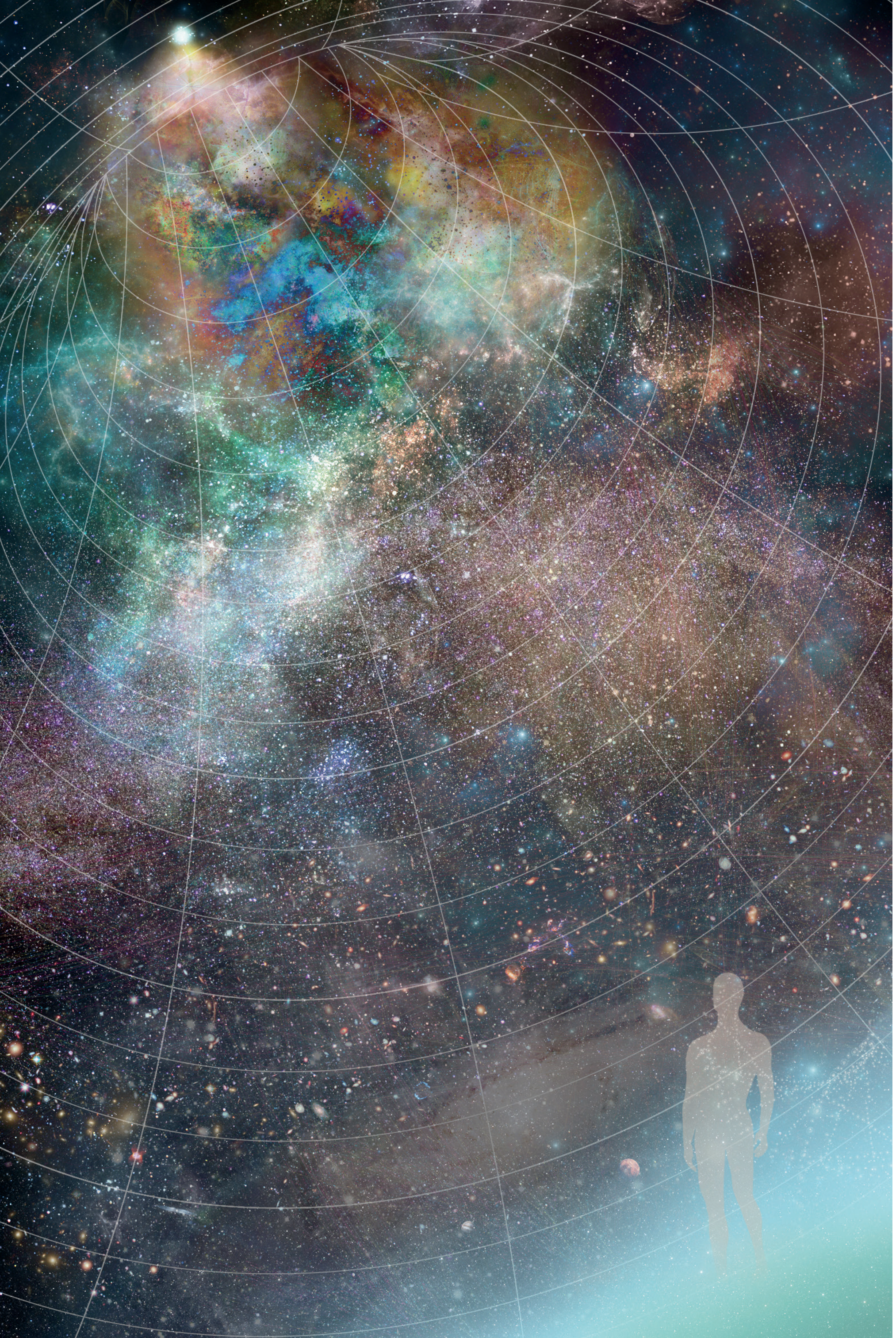
EUREKA MANIFESTO

THE MISSION FOR OUR CIVILIZATION

YURI MILNER

To my parents and Julia



EUREKA MANIFESTO

THE MISSION FOR OUR CIVILIZATION

YURI MILNER

TO THE READER

THIS BOOK CRYSTALLIZED around an idea that first formed in my childhood, when I read Iosif Shklovsky and Carl Sagan's *Intelligent Life in the Universe*. I was fascinated by the possibility that intelligent beings are out there – but also by the thought that they are right here. They are us.

The year I was born, Sagan and the astronomer Frank Drake held the first scientific conference on how our civilization might communicate with others. Later, they used the giant Arecibo radio telescope to search for interstellar messages. In the sixty years since, no such message has arrived. But a few years ago, gazing up at Arecibo alongside Frank, it occurred to me that even while the receiver remained silent, I could at least communicate with one intelligent civilization. Our own.

This manifesto is my message. It calls on us to look beyond the horizon, to see the extraordinary cosmic story that we are part of, and there to find our Mission.

CONTENTS

PREFACE:
THE TOP OF A MOUNTAIN

The Earth is blue. How wonderful.

YURI GAGARIN

It's 10:00 a.m. on April 12, 1961. My mother, Betti, is at her work station in a research laboratory. She is working on a vaccine for smallpox, and the program is at a critical stage: She's trying to prove that the live vaccine is effective. As usual in the first few hours of the morning, the room is very quiet. The only sound is the murmur of a nurse's radio in the corner of the room.

Suddenly the nurse cries out, "Listen!" She leaps up and runs into the corridor, calling out to everyone in the building: "Listen! Something incredible has happened!" Betti hears the voice of the radio anchor: "Attention, attention, all radio stations…" A news bulletin is interrupting every program in the country. For the first time in history, the anchor announces, a human being has entered space. His name is Yuri Gagarin. Betti hears a voice cry out – and realizes it's her own. Her colleagues, too, are shouting and screaming. "The first!" they chant. "The first!"

After the announcement, no one can go back to work for the rest of the day. They are buzzing. For my mother, the feeling reminds her of the day the Second World War ended, when she was fifteen years old. It's pride, elation, and something else: a sense that human civilization is surging forward again. That we have climbed to the top of a mountain. From here we can see new mountains – and know we can climb those too. We can see the horizon and want to know what lies beyond it. Our future is suddenly much bigger than our past. Our future is galactic.

Out in the street, they can't help lifting their eyes to the heavens. He really is up there. Out there. Bolted into a metal ball more reminiscent of a deep-sea diving bell than a futuristic spaceship. Flung into the sky, through the blue and out into the black.

A few months later, crowds pour into the streets around the world to see the world's first cosmonaut – in Japan, Brazil, Canada, Egypt, Italy, Germany, Finland, and the U.K. In London, an eleven-year-old boy skips school to go and witness the great man. "It was my eureka moment," he will later recall, "the realization that this bloke had been in space."[1]

Meanwhile, back home, Betti gives birth to me. And along with the miraculous gift of life, she gives me a second gift. The name Yuri.

After Yuri Gagarin: the first human being to leave the womb.

WE NEED A MISSION

Remember to look up at the sky
and not down at your feet.

STEPHEN HAWKING

Somewhere out in the blackness of space, there may be eyes that see us. Minds that read our signals. Perhaps they notice the patchwork of roads and fields on Earth's surface, the shifting composition of its air. Perhaps they understand that there is not only life here, but civilization: an intelligent species, aware of the Universe outside and beginning to venture into it. Perhaps, like my mother after Gagarin's flight, they foresee humanity surging forward, solving its problems, flowering into a galactic civilization like their own.

Looking closer, though, our observers might be surprised to find that the collective behavior of this intelligent species makes little sense.

Human beings, individually and in groups, do remarkable things. But our civilization as a whole is much less coherent. Though technological progress has a clear trajectory, human progress is chaotic. On a planet with abundant resources, we struggle to marshal them to solve our shared problems. Instead we squabble endlessly. We play zero-sum games. We focus on short-term needs, blind to long-term risks – and rewards. Collectively, we act as if we are sleepwalking and have forgotten there is a bigger reality to wake up to. A future to build.

Why?

We are so used to this status quo that it rarely occurs to us to ask the reason. We assume it's inevitable – just human

nature. Yet human nature doesn't always stop large groups succeeding at complex tasks. Businesses and nonprofits, religions and mass movements, cities and nations can coordinate thousands or even millions of people on ambitious projects. When we look at these organizations, we see that the high achievers share a trait: They know what they're trying to achieve.

Any organization that is serious about doing something significant has a *mission*. It isn't always explicit. But it's there. In the back of people's minds as they go about their work. In the roles they take on, the goals they set, and the decisions they make.

The mission of Doctors Without Borders is to "provide lifesaving medical care to those most in need." Google wants to "organize the world's information and make it universally accessible," while Facebook is trying to "bring the world closer together." Alibaba is working to "make it easy to do business anywhere." Netflix exists to "entertain the world." NASA aims to "reach for new heights and reveal the unknown." And the New York Bakery Co. strives to create "soft, chewy, generous bagels with bite."

Having a mission gives a purpose to existence, a guiding vision to our choices, and a rallying call to action. But this idea, which holds true across a broad range of human activity, from local clubs to giant international organizations, is abandoned at the largest scale. Human civilization, as a whole, has nothing resembling a shared mission. In the long term, that means we cannot thrive – or probably even survive.

But what could such a mission be? People, nations, and cultures vary wildly. Where on Earth do we look for a common goal?

Beyond Earth. If we look beyond our local horizons, we will find our Mission out in the Universe: in the **Universal Story** we are part of – and whose next chapters we can choose to write.

OUR MISSION

*We are a way for the cosmos
to know itself.*

CARL SAGAN

IMAGINE EVERYTHING. Everything around you. The sky above, and the miles of rock beneath. Imagine Tokyo. Idaho. Africa. Jupiter. A billion trillion suns, spinning in silence.

Your mind holds the idea of it all. That alone is remarkable. But there's more. All of it – every crumb of matter, every glint of light – was once squeezed into a sphere about the size of your head. Most amazing of all, your mind can imagine that sphere. It existed – for an instant – nearly fourteen billion years ago. And somehow you know about it.

The journey from the little sphere to the mind that imagines it – and beyond – is the story of everything. The **Universal Story**. The beats of this story are a series of "phase transitions"[2]: critical changes of state, as when water freezes to ice. These transitions shaped order out of chaos. They permitted, here and there, patterns to emerge and hold their form, enduring against time.

The sphere, although it is incredibly hot and unimaginably dense, is also smooth, uniform, perfectly simple. Well, almost perfectly. It contains microscopic flaws: seeds of complexity that will one day grow into the grand structure of the Universe. Complexity that will one day include us, the storytellers.

The sphere inflates, at astonishing speed, to vast and ever-expanding size.

For hundreds of thousands of years, the swelling

cosmos contains a seething plasma of particles. Then comes a phase transition. Matter cools enough to cohere into stable structures – atoms – simultaneously freeing light to flow through space. For the first time, there is a visible Universe – though nobody to see it. Over eons, immense banks of gas pool in wells of gravity, whirling into the forms of galaxies and stars. Some of the stars burn out and explode, seeding the cosmos with more complex elements – carbon and iron, nitrogen and oxygen – that will one day build your body and house your thoughts.

After about nine billion years, a cloud of gas, enriched with these embers of dead stars, swirls itself into a new star: our Sun. The debris clumps into planets. Magma cools to rock, steam to water.

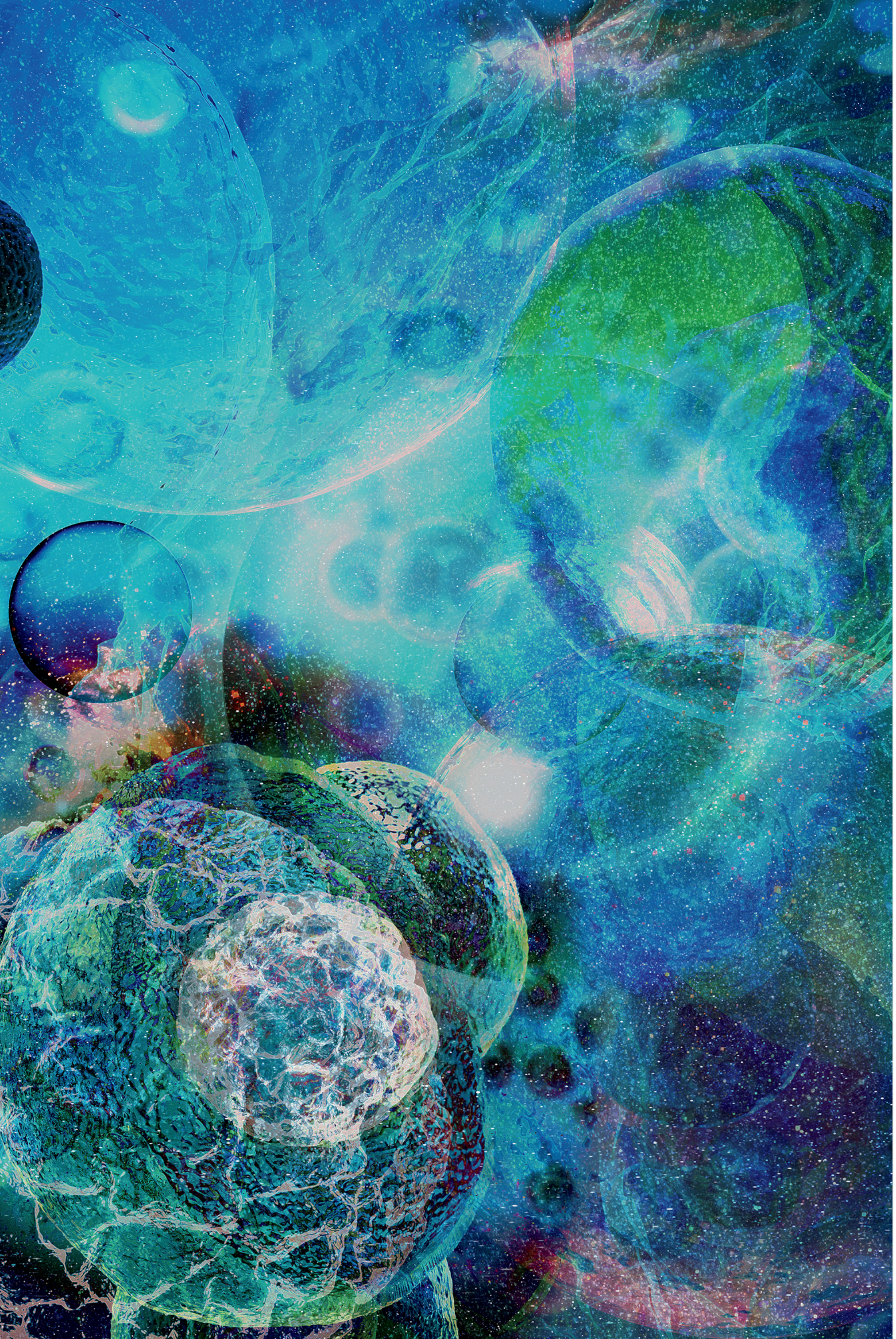
And now, on the third planet out, a new phase transition begins. Deep in an ocean or on some ancient shore, spiral-shaped ribbons of molecules, sealed inside bubbles, have found a way to copy themselves. As the bubbles – the first cells – move through their environment, they do something that's never been done before, possibly anywhere in the Universe. Reacting to the conditions around them, absorbing nutrients and avoiding hazards, they develop an ability to *model* the outside world.

It's a crude model, which captures only the smallest fragment of primeval Earth. But over the eons, a cell with slightly better models will tend to pass them on through its genes, and so the models improve in accuracy. The cell, tiny and simple as it is, holds a sliver of knowledge.

For over a billion years, there are only single cells. Then comes a leap in complexity – another phase transition: one cell gets inside another and joins forces with it. The descendants of this innovator branch off into the wild diversity of complex life. Colonies of cells begin to cohere, acting as single organisms. With multiple models of the world combined together, the sliver of knowledge they possess can expand. Organisms comprising trillions of cells develop sensory organs and nervous systems, then eventually brains – organs that can build and update more sophisticated models and select the ones with the best predictions. This enables them to model wider slices of the world, far beyond the few drops of water that were all the single cell knew.

The next phase transition occurs when intelligent animals find ways to communicate, spreading models beyond the individual brain. By pooling knowledge within their group, they transmit it across space; by teaching it to their offspring, they transmit it across time.

This transition accelerates rapidly when humans arrive on the scene. With language, and later writing, we can spread knowledge not just among personal contacts, but across continents and over generations. Our shared store of



models accumulates, combining into a deeper and richer picture of the world than has ever existed before on the planet – or perhaps in the cosmos. Humans do more than know: We know that we know, and wonder about what we don't know.

In our little corner of the cosmos, the miracle has happened. Mind has formed from matter.

And yet, for thousands of years, we remain in the dark. We long to understand the nature of the Universe, the origin of life, who we are and what we're here for. But we know almost nothing of this **Universal Story** – nothing about trillions of suns or trillions of cells. Our brains are modern, but our understanding is still primitive.

Phase transitions, though, are rarely instant. When water changes to ice, it doesn't happen all at once. First, a few crystals form – seeds of a new state. Most dissolve again. Then one survives, attracts others to it, and the new state spreads across the surface.

The Scientific Revolution begins in the same way. Here and there, now and then, a few original thinkers uncover a little more of the **Universal Story**. In ancient Greece, India, and China, in the medieval Islamic world, big ideas in mathematics, astronomy, and other fields gradually bubble to the surface. Then, in a few European cities and centers of learning, the creation of knowledge begins to accelerate. Discoveries in science emerge alongside, and cross-pollinate with, new ideas in philosophy, art, literature, architecture, music, and other fields. Artists, like scientists, are thirsty for knowledge. They too aim to model the world, and develop new tools like 3D perspective. But their paintings and sculptures – the mass media of the day – also project outward: They feed and sustain a shared culture of truth-seeking, rational argument, and criticism. Little by little, enlightenment begins to crystallize.

In the sixteenth century, in places like Florence and Venice, robust and fast-spreading crystals are forming. At their centers are thinkers like Galileo. Restless, curious, stubborn to the point of peril, Galileo pioneers many of the big ideas that will enable scientists to piece together elements of the **Universal Story**. The motions of bodies moving through space and falling under gravity.[3] The principle of relativity.[4] Even the concept of the speed of light.[5] And he expresses these ideas not just in words but in the crystalline language of mathematics. Unlike verbal descriptions of the world, mathematics is precise, objective, and universal. It captures the essence of natural phenomena, and enables the construction of much more comprehensive models, which often describe more of the world than they were designed to. These mathematical models are internally consistent and free of unnecessary features.

Combining mathematics with the existing tools of knowledge transmission – language, writing, and printing – and the wider culture of ideas sparks a phase transition in the evolution of science. Galileo and his peers can now rapidly generate competing models, compare them, critique them, and test them on the world. Throw out the bad ones, hone the good. Then use the good ones to build new technologies that can peer far beyond the human scale, exploring the Universe and finding new data that in turn inspires new fundamental questions. In the process, the new, better models come to predict more and more of the world, more and more accurately.

Indeed, one of the most powerful drivers of progress is the coupling of science and technology into a kind of feedback loop. Galileo's theoretical understanding of optics enables the practical design of the telescope; in 1610, his telescope reveals the moons of Jupiter; and the knowledge of that system of orbiting bodies feeds back into theory, providing convincing evidence for the heliocentric model of the solar system proposed by Nicolaus Copernicus the century before. This discovery, too, embodies a deep idea, often called the Copernican principle: that the Universe is far bigger than us. It does not revolve around the Earth, human beings, or our concerns.

The science-technology feedback loop lets us sense the true scale of reality. The telescope looks up to the heavens, the microscope peers into the inner world beneath the surface. In the next centuries, that sense of scale only grows. We discover that we are just one planet, in one star system, in one galaxy among hundreds of billions more. In 1861, a technological question – how to send a transatlantic telegraph message[6] – drives the physicist James Clerk Maxwell to isolate himself on his Scottish Highlands estate and formulate the laws of electromagnetism. These mathematical equations lead him to predict the existence of radio waves.[7] The detection of these waves by Heinrich Hertz twenty years later leads to the invention of radio telescopes – which in turn capture the afterglow of the first light released at the dawn of the Universe.

Today we know that the visible Universe is over ninety-three billion light years across – and it may be just one in an infinite Multiverse. We also know that space teems with activity down far beyond a trillionth of a millimeter. To those revelations about space we have added the immense scale of time: the nearly fourteen billion years of the Universe's existence, the trillions of years that likely lie ahead. And even at our own scale, in the realm of living things, we have found there is far more of the world than we thought: We are one tiny twig on a tree of life sprouting millions of species, entwined with interdependent networks of dizzying complexity, from the microbe to the ecosystem. The image of the Earth at the heart of all things, with humanity its crowning glory, has given way to a grander vision of the cosmos, but a humbler view of ourselves.

Yet the Copernican principle can be pushed too far. Although we are on the margins, we are not insignificant. We may be a tiny part of the cosmos, but we are also an extraordinary part. Perhaps unique. We are significant not because of where we are in the Universe, but because of *what* we are. Because we have the capacity to explore and understand that Universe, far beyond the bounds of our own little slice of space and time – and by doing so, to discover the **Universal Story**.

It is amazing to contemplate how we reached this point: how a lifeless, mindless Universe gave birth to structure; how that structure grew more and more complex, until through it the Universe began to build a model of itself – began to tell its own Story. The simplest cell already had part of the Story to tell, written in its genes. A tiny part, true – a fragment of a sentence, describing a droplet of ocean on a primeval planet. But as genes built brains and brains built cultures and cultures built a shared store of knowledge, more and more fragments became legible. And when the Enlightenment crystallized and modern science was born, whole pages came into focus. The chapters of the **Universal Story** that we have written so far extend across an extraordinary range of space and time: from the quark to the quasar, from the Big Bang to our own age, and beyond.

We are the Universe waking up. Opening its eyes after a fourteen-billion-year sleep. Beginning to know itself. To explore its form. To remember its past and imagine its future. To tell its story. We are a fragment of creation that knows what happened in the first second of its birth. Of all the atoms scattered from ancient stars, it is ours – possibly ours alone – that are awake.

We were, in a sense, chosen. Not deliberately. But in the dance of chance and time, we found ourselves in a form that can explore and understand. This is our gift. Our precious birthright. To be awake. To have minds formed from matter. To look out at the world and understand.

So the unfolding of the **Universal Story** has not just given us existence. It has sent us a message, written in the very first cell and still encoded in every cell of our body. And this message is our Mission:

Explore and Understand our Universe

To explore – with our eyes and our technologies – as far as we can, out across the reaches of space and time, down into the heart of light and matter. To understand everything: the truths of mathematics, the laws of physics, the workings of life and the mind itself. To extend and refine the **Universal Story** handed down to us through billions of years.

Unlike all other missions, this one is fundamental. It is not invented but discovered, like a law of nature. It arises organically from the evolution of the cosmos – from the **Universal Story** itself – in a series of phase transitions from mere existence to awakening.

We have the opportunity to embody that extraordinary transformation, to embrace it and carry it forward into the future. To stay awake. **To explore and understand our Universe.**

That means all of us. Not just the scientists who make the discoveries. We all have a stake in this Mission. Because we are at a critical point in its progress. Because the fruits of exploration and understanding will benefit everybody. And because without our commitment to the Mission, the Universe could close its eyes and drift back into sleep.

WHY WE MUST EMBRACE THE MISSION

Nothing in life is to be feared,
it is only to be understood.

MARIE CURIE

THE UNIVERSAL STORY is far from finished. It may be just beginning. We don't know how awake the Universe can become – what breadth of exploration, what depth of understanding it can produce. But we know that its awakening is inevitable. The laws of physics tell us that islands of complexity like the solar system and the Earth will continue to form for many billions of years to come. It seems inevitable that evolution will, over time, create life, minds, and civilizations that will keep expanding the scope of their discoveries.

HOW LONG CAN WE KEEP TELLING THE STORY?

Our Mission is to explore and understand for as long as we can. But how long is that? Assuming that we are able to survive into the far future, our ability to keep thinking may be constrained by recently discovered cosmological phenomena.

Appendix, p. 81

But if the Universe is destined to tell its own story, then why does it matter whether *we* are the storytellers? Why can't we be content with the broad sweep of the plot that our ancestors already figured out, and take it easy from now on?

There are two principal reasons why it is essential that we embrace the Mission ourselves:

THE COSTS OF FAILURE

If we fail to embrace the Mission, we risk the very future of our civilization.

THE REWARDS OF SUCCESS

If we succeed in embracing the Mission, our civilization can fully realize its potential.

THE COSTS OF FAILURE

FAILED ENLIGHTENMENTS

Let's step back to that moment on primeval Earth when two cells merged together. That union, which was the genesis of all complex life, came most likely over a billion years after the appearance of the first cells. How many "nearly" moments were there in those billion years? For all we know, there were countless dawns of complex life – but all except one were false dawns. Perhaps, had a few chance events gone differently, it might have taken a billion more years to build a complex cell.

The same is true of the other great leaps of evolution.

Eons of painstaking growth and development can count for nothing in the face of chance catastrophes. The Permian–Triassic extinction event wiped out over ninety percent of species on Earth, including most of the land animals. And according to some scientists, seventy thousand years ago the human population may have dwindled to as little as a few thousand people.[8]

Phase transitions are not irreversible. Islands of complexity are constantly pounded by the surrounding ocean of chaos and often eroded to nothing. Ice can melt. Life can fade. And enlightenments can fail.

EINSTEIN ON THE RUN

The danger of enlightenment failing may seem remote to us today. In our technological and information-driven society, surely science is safe from persecution? But just 88 years ago, the world's greatest scientist was on the run for his life – from the government of one of the most cultured nations in history. And his theories – among the most accurate models science has ever produced – were condemned.

Appendix, p. 85

To see this, we need only look back at the long, slow birth of science. Before the Scientific Revolution, there were

proto-revolutions throughout history. In ancient China and India, mathematicians developed a decimal number system. In the cultures of Athens and Egypt, they advanced algebra and geometry, modeled the motions of the planets, and classified living creatures. In Persia, Iraq, and Islamic Spain, scholars revived those Greek ideas and built on them, for the first time developing astronomy that was more than astrology, chemistry that was more than alchemy, and the beginnings of medicine that was more than folk remedies. But all these grains of rational inquiry dissolved before they could crystallize into a full-fledged Scientific Revolution.

Sometimes it was through lack of support in the broader culture. Sometimes it was political turmoil, as in ancient Athens, and in Florence itself, where just a century before the time of Galileo an embryonic enlightenment was suppressed by the puritanical cult of Savonarola. In 1497, soon after the charismatic preacher's takeover of the city, books were burned in a massive public bonfire, and the culture of intellectual openness was replaced by conformity. Florence – and perhaps our civilization – were lucky that this period of turbulence was short-lived.

For just as the growth of a crystal depends on the surrounding conditions, the emergence of an enlightenment depends on a wider culture in which critical thinking and open discussion are tolerated, and there is a general commitment –

not just among scientists – to the value of exploration and understanding. Today, the printed word and the Internet have disseminated scientific ideas so widely that they could never be lost, even if society turned against them. But such a turn could still drastically slow the pace of progress. Because new discoveries do not just spring from old ones. They require a questing, questioning, and tolerant culture around them.

We sometimes tend to think that the Scientific Revolution won the day long ago. But a true revolution requires the old order to be overturned. In the case of our civilization, is the pre-scientific mindset really a thing of the past?

Actually, irrational and pseudoscientific ideas remain highly popular today, whether distortions of cosmology, healthcare, genetics, or history. According to a recent poll, nearly eighty percent of respondents expressed belief in at least one unscientific idea.[9]

And although some of us like to think of ourselves as "pro-science," our cultural preferences make clear that it is way down our list of priorities. We admire the stars of sports, entertainment, and sometimes even entrepreneurship, but we do not truly celebrate scientific heroes or their discoveries. With the passing of Stephen Hawking in 2018, could we even name one of today's leading scientists? For many people, science is something that affects our lives at best only via technological breakthroughs and the occasional news article. And even then, an epochal discovery can generate fewer headlines than a story about the love lives of celebrities.

This low level of public interest is not trivial, because it leads to low levels of public funding of science. Even when it comes to programs with clear societal benefits, such as the development of new types of vaccines, it can take a major pandemic to bring home the value of basic research. But for fundamental science with no immediate medical or technological benefits, investment is wildly inadequate given its significance for our future. For every Large Hadron Collider built, countless promising ideas never make it past the proposal stage.

This is shortsighted for two reasons. First, because we never know when an idea will bear fruit. When Newton and Leibniz invented calculus, they did not have Moon landings in mind. When Gregor Mendel discovered the laws of inheritance, he did not contemplate that lives could be saved by gene editing. When Einstein dreamed up the theory of general relativity, he never dreamed it would make GPS possible. But secondly, and more profoundly, the value of science does not depend on its applications. It is our only way to tell the **Universal Story**, and it needs no other justification.

Even so, while the fundamental purpose of science is not to solve practical problems, it is still our only hope of solving them. Without science, our advance into the computer age cannot continue. Without science, even the society we have now cannot survive long-term. Science is the only reliable method we have found for predicting the future and gaining some control over nature. If we allow scientific progress to stall, it will ultimately mean the end of our civilization.

Four hundred years after Galileo, we are still in the early stages of the Scientific Revolution. It is up to us to accelerate it, and launch a new Enlightenment in which it can flourish.

In his book *The Beginning of Infinity,* the physicist David Deutsch vividly brings home the significance of all those failed enlightenments of the past:

> *"If any of those earlier experiments ... had succeeded,*
> *our species would be exploring the stars by now,*
> *and you and I would be immortal."*

Our ancestors – some of them – failed us. We must not fail our descendants.

EXTINCTION EVENTS

Some of the threats to our civilization are self-generated. Global war, bioterrorism, and anthropogenic climate change are serious challenges to the whole of humanity, as well as clear examples of problems that would be diminished if we could come together with a sense of unified purpose as a species and a civilization.

Other dangers emanate from beyond our planet. The most pressing such risk is a collision with a large asteroid or comet. Events like the 1908 Tunguska collision, when an object around one hundred meters in length flattened eight hundred square miles of forest, happen about once every two hundred years. The probability of an encounter with an object larger than ten kilometers across, like the one that extinguished the dinosaurs, is extremely low. But of course, if you wait long enough, the improbable becomes inevitable. Stephen Hawking estimated that "although the chance of a disaster to planet Earth in a given year may be quite low, it adds up over time, and becomes a near certainty in the next thousand or ten thousand years."[10] There is no particular reason to think that deflecting such asteroids is beyond our powers over that time frame – indeed, we may even have the technology already. In the last decade, the European Space Agency's Philae lander touched down on a comet, and Japan's Hayabusa2 on an asteroid. If such a body were homing in on Earth, it is plausible that a spacecraft could alter its trajectory, either by impacting it or by firing rockets from its surface to kick it off collision course. Much less likely, but much less easy to evade, is a planetary impact: for example, the orbit of Mercury and other planets could become unstable, putting us at risk of collision.

One way to mitigate a disaster to planet Earth is to spread out into space. Elon Musk is working on that –

specifically, the colonization of Mars. In the long term, though, even Mars must be a stepping stone to more distant destinations. This is because two adjacent planets could be simultaneously affected by the Universe's more violent events. A nearby supernova – the final explosion of a red giant star – could shower the solar system with immensely energetic gamma and cosmic rays. A close enough encounter with a large black hole could also imperil more than one planet at a time.

Even if we manage to avoid all these dangers, we know that much farther into the future the Earth and probably Mars are on course to become increasingly hostile to life. Within the next one to two billion years, unless we can find a way to stop it, the increasing temperature of the sun will strip the Earth's water into hydrogen and oxygen, with most of the hydrogen lost to space.[11] After about five billion years, the Sun will burn up its fuel and expand toward the orbits of Earth and Mars. Five billion years may seem plenty, but, in a Universe destined to last for trillions of trillions of years, it is an instant. Perhaps by that time our descendants will have reached a scientific and technological level at which they can extend the distance of planets from the Sun. Even in this case, to survive much longer we will eventually have to spread farther into the galaxy. But the key point is that both control of the solar system and escape from it would be impossible without embracing the Mission of exploring and understanding our Universe.

DEATH BUBBLES

The most perilous existential risk may lie in another kind of phase transition, known as "vacuum decay" or, less technically and more dramatically, "death bubbles." Remarkably, this is a danger that would arise from literally nothing: from empty space itself. If they exist, death bubbles may be inescapable, but scientists believe that a sufficiently advanced civilization could, in principle, evade them for extremely long periods of time. *Appendix, p. 87*

When we look out into space, there is another potential risk to consider, which depends on one of the most important questions in science: Are we alone? The two possibilities – that we are the only intelligent civilization capable of exploring and understanding our Universe, or that there are others out there – may have important implications for our long-term survival and the progress of the Mission.

THE GREAT FILTER

In 1961 – the same year as Gagarin's flight – the astronomers Carl Sagan and Frank Drake organized the Green Bank conference, where Drake presented his famous equation estimating the number of potential communicative civilizations in the Milky Way. For the next half century, a small number of astronomers kept up a heroic search for radio and optical transmissions, but so far have found no confirmed signals of artificial origin.

BREAKTHROUGH INITIATIVES

Life in the Universe is the area of science with perhaps the biggest mismatch between its level of profundity and its level of funding. On the bright side, that means it could offer considerable scientific return on investment. *Appendix, p. 89*

There could be many reasons for this. It may well be that we have just not looked hard enough. Jill Tarter, a pioneer in the search for intelligent life, famously compared the searches undertaken in the decades since the Green Bank conference to dipping a single glass into the ocean and wondering why you don't catch a fish. The Universe is vast, and however many islands of complexity there may be, they could still be far away. And even if we are looking in the right places, we may be looking in the wrong way: Maybe the aliens have developed methods of communication that we cannot recognize, or even intercept.

Alternatively, perhaps the silence means exactly what it sounds like: there is nobody there but us. For all we know, there may be some roadblock, or Great Filter,[12] that makes the long-term evolution and survival of life or civilizations extremely unlikely. Perhaps it takes an extraordinary series of random molecular interactions for life to emerge from simpler ingredients. Or perhaps cellular life is common, but the emergence of complex organisms with knowledge-bearing brains is cosmically rare. Maybe most intelligent civilizations self-destruct. Or maybe one of the existential risks from space is unavoidable.

The possibility of a Great Filter is one of the strongest incentives to pursue the Mission. Science is the only way to find out whether it lies ahead of us or not. If it does, science and technology are our only chance to avoid it. And failure to avoid it could have consequences far beyond our own fate.

Because if indeed we are alone, then our responsibility to the Mission is truly immense. It means the awakening of the Universe, the telling of the **Universal Story**, is for now wholly realized through us. We are dependent on the Mission for our survival, and the Mission may, for now, be dependent on us. Since, in this scenario, only one advanced civilization has crystallized since the Big Bang, the chances of this happening must be very low, and therefore it could take many billions of years for another such civilization to arise elsewhere.

Fifty years ago, the Voyager probe was about to pass Saturn, capturing its lonely beauty in flyby photographs. But Carl Sagan was not satisfied with those images alone. He lobbied NASA[13] to do something they had not intended. To turn the camera and look back – just as Gagarin had looked back – to where it had come from: to our blue planet.

Sagan understood how our capacity for knowledge gives us fundamental significance. But he also understood the intimate link between our significance and our fragility. When he convinced NASA to turn Voyager's camera back to Earth and take the photo that would become known as the Pale Blue Dot, he was looking for much more than an iconic image. He wanted to show humanity the preciousness of our place in the cosmos. He wanted us to feel what our loss would mean: The light of understanding – perhaps everywhere and for ages to come – would flicker out.

COSMIC NEIGHBORS

But what if we are not alone? The consensus among astrobiologists today is that at least primitive cellular life is likely to be ubiquitous in the cosmos.[14] Even twenty years ago, we did not know if there were more than a handful of other planetary systems beyond the solar system. Then came NASA's Kepler space telescope, and the Copernican revolution happened all over again. It turns out that, statistically speaking, every

star has at least one planet. Even when it comes to Earth-like planets – rocky worlds of a similar size to our own, in the habitable zone of their star – there may be many billions in our galaxy alone. And there are about a trillion galaxies in the observable Universe. So, incredibly, the number of possible homes for life is comparable to the number of grains of sand on all the beaches on our planet. Even if life is very unlikely it could still be common, in turn raising the likelihood that intelligent life is out there, too. What would that mean for the Mission?

Experience on Earth tells us that islands of complexity, as they grow, coexist in a Darwinian landscape where cooperation is possible but competition is everywhere. The same may be true at the galactic level. If other civilizations are hostile, they represent perhaps a significant extinction risk. Since our own civilization is only a few thousand years old – a microsecond in cosmic time – any civilization we meet is likely to be vastly older, and therefore could be vastly more advanced, scientifically and technologically. Another lesson from our own experience on Earth is that encounters between more and less technological civilizations tend to go badly for the latter. We would be prudent, then, to advance our civilization as rapidly as possible before we bump into any aliens.

It is possible, however, that the distances and timescales involved in space travel are so great that wars of conquest and resource extraction are not worthwhile. More significantly, any civilization advanced enough to spread out into the galaxy may well be uninterested in warfare because they have discovered the same Mission: **to explore and understand our Universe.**

Even if the aliens are both friendly and far more advanced, it would be deeply unwise for us to relax our ambitions and rely on the aliens to pursue the Mission. In a Darwinian landscape, no one is safe from extinction, and in an uncertain Universe no civilization, however sophisticated, is guaranteed to survive indefinitely. So to reduce the odds of the Mission being derailed, it makes sense to maximize the number of existing civilizations and devote our resources to deepening our understanding and spreading out into space.

Moreover, life and civilization, however common they may be, are important phenomena – among the wonders of the cosmos. Part of the Mission is to explore and understand them. Even if the failure of our own civilization did not constitute an ultimate tragedy for the Universe, it would still be a terrible loss. Along with everything else, we would miss out on the possibility of meeting those other minds, learning from their ideas, and becoming a galactic civilization.

THE REWARDS OF SUCCESS

We have seen the costs of failure to pursue the Mission: the stalling of the Scientific Revolution; a possible existential threat to our civilization and our species; and – if we are alone – the return of the cosmos to oblivion, perhaps for eons. But what about the rewards of success? The prize of pursuing the Mission is the emergence of a civilization whose grandeur we can only guess at, and minds whose capacities we cannot even imagine.

TECHNOLOGICAL PROGRESS

Over the last century and a half, the science-technology feedback loop has generated successive waves of progress: industrialization, electrification, computerization.

Although most of the pioneers of industrialization were engineers and inventors, it was the Enlightenment culture of scientific criticism and problem-solving that formed the ground in which their ideas took root. James Watt, whose steam engine powered the early Industrial Revolution in Britain, had worked as a maker of scientific instruments, and this gave him the background to theorize about the inefficiency in existing engines and experiment systematically until he had created a far more effective design. Meanwhile, breakthroughs in chemistry and materials science produced the new substances, from steel alloys to aniline dyes, that proved crucial in the development of modern industry.

Magnetism and some forms of electricity had been known since ancient times. But it was only in the nineteenth century, through the work of scientific minds like Ben Franklin, Michael Faraday, and James Clerk Maxwell, that the two forces were rigorously investigated, unified, and tamed in the service of human prosperity. These thinkers' ideas have lit up the planet, sent our images and messages across it at the speed of light, and efficiently distributed the fruits of modern culture to every corner of it.

As for computerization, it can be traced directly to quantum theory. That is one of the most abstract theories in science, but without it, engineers could not have turned semiconducting crystals into transistors. So the quest for a fundamental theory of matter and light, driven purely by the urge to understand the Universe, which culminated in the discovery of quantum mechanics, has transformed almost every aspect of society – and will soon transform it far more radically.

Despite these advances, today we confront many challenges, from climate change to energy scarcity to incurable diseases. For most of these problems, only science will provide the solutions. Redirecting a much larger proportion of resources to basic research is the most effective way to address them.

GALACTIC CIVILIZATION

One area in particular where progress can be accelerated dramatically is our exploration of the solar system. Humanity's farthest footprint beyond Earth is on the Moon, where we left it over half a century ago. What was once a mark of our ambition – rising to the challenge laid down by Gagarin – is now a silent symbol of our stagnation.

That is changing, though. Today, alongside government space programs, private initiatives from entrepreneurs like Elon Musk and Jeff Bezos have advanced technologies and captured the public imagination in ways not seen since the 1960s. This new energy must be sustained and encouraged.

A new commitment to exploration, likely spearheaded by robotic missions, would allow us to renew the promise of Gagarin's flight: that our destiny is to be a galactic civilization. As we have seen, we will have to be, for our own survival. But we should also want to be. Once the ancient Polynesians realized that the world was much vaster than they had imagined, with countless lands and islands to inhabit, the idea of just staying at home, content with that knowledge and no more, was impossible. They had to go there.

Today we are in the same boat. We now have a glimpse of the bounty of worlds the Universe has to offer. Even beyond the Earth-like planets identified so far, we know there are super-Earths, water worlds, probably planets made of diamond. And that's not touching on the potentially habitable moons, like Pandora in James Cameron's *Avatar*, and who knows what other worlds beyond even the visions of science fiction writers. Far into the future, our descendants – whether they are carbon, silicon, or both – can explore these wonders and settle on some of them. And beyond the worlds we could actually land on, there are countless other extraordinary places and exotic objects to visit.

Human eyes – or most likely those of our machines – might be the only eyes to witness these treasures. What a profound waste it would be if they were left unexplored. And what a waste of our civilization's potential if we were to remain defined by our humble beginnings on this one little planet rather than by a grand future in the galaxy.

The journeys of our ancestors to previously uninhabited lands resulted in the foundation of whole new cultures – art, music, storytelling, ways of working and living together that would never have been dreamed up without the inspiration of the new. If such flowerings can be inspired by the deserts of Australia or the islands of the Pacific, what heights of creativity could be unleashed by entirely new worlds?

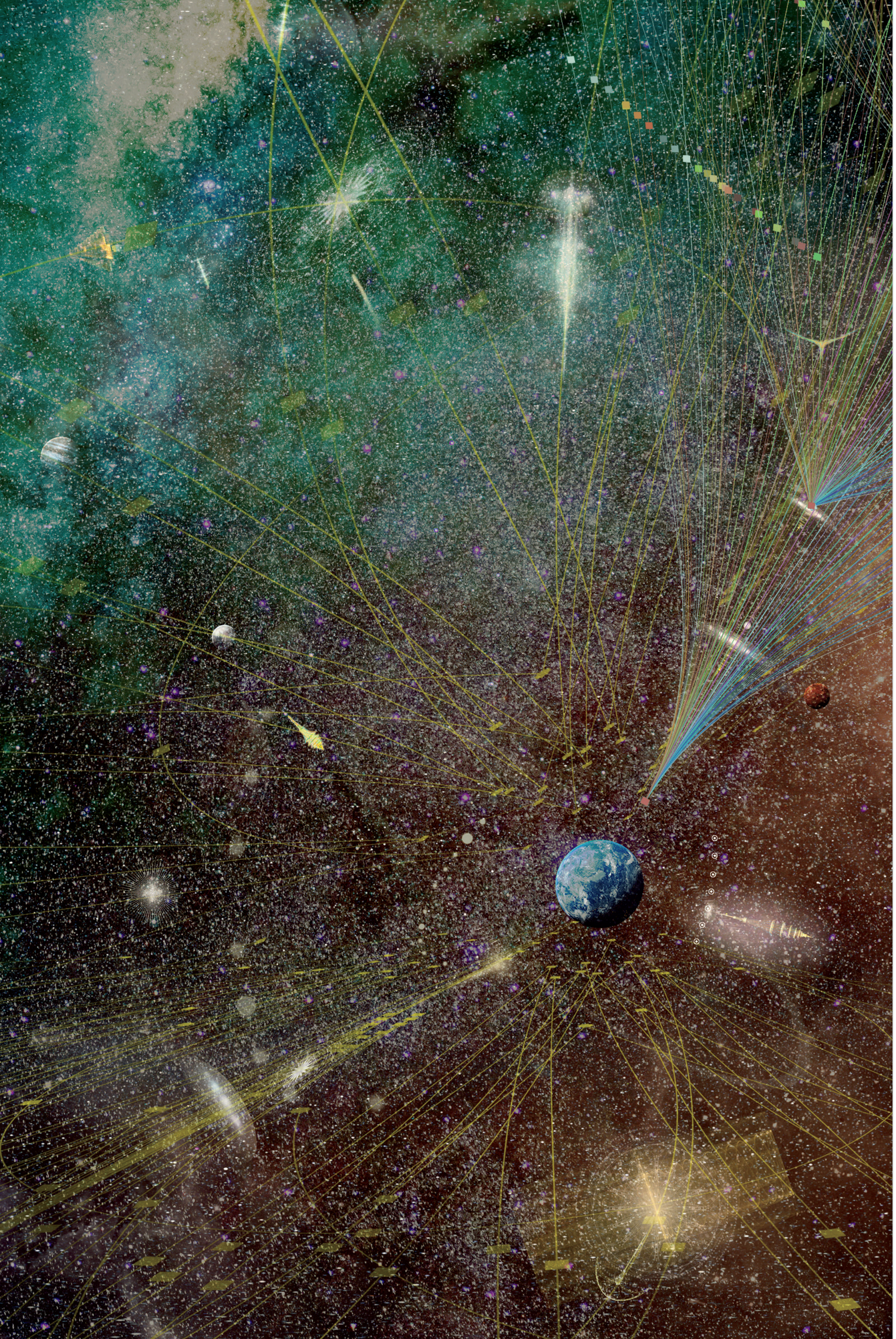
As our descendants explore and understand more and more of our Universe, they can create new forms of culture and ways of life, generating a diversity of civilizations and

crystallizing an expanding sphere of enlightenment far beyond Earth.

INTERSTELLAR TRAVEL

Yuri Gagarin brought our civilization to space, and eight years later we reached the Moon. But humans are poorly designed for space travel. We are fragile, unreliable, and need extensive life-support systems. It is notable that most space missions today are robotic. What might be the path to spreading civilization beyond our stellar neighborhood?

Appendix, p. 91



THE SIGNIFICANCE OF OUR MOMENT

The tools and technologies we've developed are really the first few drops of water in the ocean of what AI can do.

FEI-FEI LI

It is inspiring to think about the possibilities of the far future. But something remarkable is already happening to our civilization, right here and now.

There is reason to believe that we are at a pivotal point in the **Universal Story**. The Story has unfolded through phase transitions like the emergence of cells, complex life, brains, and science itself. And the dawning in the last decades of the computer age could represent the start of a new phase transition, transforming the nature of knowledge.

Computers are speeding up and scaling up the already powerful effects of networks. With the Internet and social media, the capacity for collective thinking that was previously enhanced by language, writing, and printing has reached another level. Instant global communication, information sharing, and crowdsourced collaboration are now routine; and with the next generation of network technologies, virtual and augmented reality and the Internet of things will become important parts of our lives. What we are witnessing is a sea change in collective intelligence – a rapid expansion of complexity and connectivity at the global level. Knowledge, intelligence, and understanding are becoming planetary phenomena.

Of course, computers are not the first tools we have found to help us refine our models of the world. But they promise something new again. We may soon be able to

externalize not just our existing models but also our *ability to create new models*. Artificial intelligence (AI) has the potential to exponentially improve its own ability to model the world, generate predictions, collect data, and perform experiments. In other words, to do science, to tell the **Universal Story**. A recent survey asked AI researchers to estimate when this leap would come; the average prediction was about forty years.[15]

Already, today, machine learning can have the character of a black box: we do not always understand *how* it finds the solutions that it presents to us. As AI advances, we might reach the stage when we lack the mental architecture to comprehend the solutions themselves. And then, perhaps, the nature of the very questions these machine minds are asking might prove beyond us.

If we are standing on the brink of a new phase transition, in which human intelligence, even networked together, will no longer be the highest intelligence on Earth, then such a leap has the potential to radically accelerate the pace of scientific progress. If, as a global society, we were to truly embrace the Mission, we could focus the development of artificial intelligence toward it – toward exploration and understanding of our Universe. This could not only transform our lives and our civilization, but significantly accelerate the Mission itself. After all, from the point of view of the Mission, the most important issue is not which type of intelligence advances fastest and farthest, but that *some* intelligence does. If the discoveries of the future are made not by us, but by the silicon minds we birth into the world or by a global human-silicon system, our destiny will still be fulfilled.

Will the future of exploration and understanding be human? Will it be machines, uploaded with human or AI minds? Or planet-size computers? Perhaps it will be all of these, and new forms of intelligence that we have yet to conceive of. From our vantage, we cannot possibly predict them: That would mean predicting the scientific discoveries that will enable them. But either way, it is crucial that we do what we can to direct the trajectory of this phase transition – now, while we still have control over it – toward the Mission. That means that a key contribution to the next, crucial stage of the Mission can be made by the technologists who are working to bring AI to fruition. If they succeed in building a mind that explores and understands, they can set the scene for a new and amazing chapter of the **Universal Story**.

HOW TO ADVANCE THE MISSION

Eureka!

ARCHIMEDES

THE GREATEST HEROES of our civilization are not only the soldiers and firefighters, the sports stars and movie stars – or even the astronauts. The ancient polymath Archimedes did not need to go to the Moon to make a giant leap for humankind; he did it by stepping into his bath. The story goes that King Hiero II of Syracuse had asked him to determine whether his crown was pure gold. Climbing into his tub one day, Archimedes realized that the water he displaced was equal in volume to his body. By the same technique, the crown's volume could be calculated, and its density could be compared to gold's. Too excited about his discovery to bother dressing, he ran into the street naked, shouting "Eureka!" ("I have discovered it!").[16] This reaction was wholly justified. For the principle he had identified – unlike conventions about public nudity – holds true everywhere in our Universe.

Not that scientists are lacking in the more traditional heroic virtues. Galileo risked his life to advance knowledge. Marie Curie gave hers. For most of his life, Stephen Hawking was confined to a wheelchair, yet perhaps he saw more of the cosmos than any astronaut has – or will. In his imagination, he traveled at the speed of light, plunged into black holes, and voyaged back in time to the first moments of creation. His intellectual flights took just as much courage, resilience, and spirit of adventure as Gagarin's physical flight.

This capacity to explore and understand is our great gift from the Universe. Nevertheless, not everyone can be a Hawking or a Curie. These are heroes of our civilization, and not all of us can be heroes. But all of us can play a part in advancing the Mission: **to explore and understand our Universe**. The Scientific Revolution and enlightenments of the past were created not only by scientists like Galileo, but by that wider culture that inspired and nurtured them: the artists, musicians, writers, architects, technologists, and everybody who contributed to the progress of our civilization. And we too, by supporting or even just embracing the Mission, can provide the fuel to accelerate the Scientific Revolution to unprecedented speeds, and kindle a new Enlightenment that shines far into the future. By implementing the following plan of action, we can reorient our society around creating the Eureka moments that define who we are and drive us onward.

PLAN OF ACTION

- INVEST RESOURCES INTO FUNDAMENTAL SCIENCE AND SPACE EXPLORATION
- ENABLE ARTIFICIAL INTELLIGENCE TO DRIVE SCIENTIFIC PROGRESS
- CELEBRATE SCIENTISTS AS HEROES
- FOCUS EDUCATION ON THE UNIVERSAL STORY AND USE THE POWER OF ART TO TELL IT
- SPARK A NEW ENLIGHTENMENT IN WHICH EVERYONE CAN CONTRIBUTE TO A SHARED CULTURE OF KNOWLEDGE

INVEST RESOURCES INTO FUNDAMENTAL SCIENCE AND SPACE EXPLORATION

Make funding commensurate with the true importance of science to our lives and our futures. Prioritize fundamental research, because that is the most fertile ground for transformative discoveries and technologies; and accelerate our progress toward becoming a truly spacefaring civilization.

ENABLE ARTIFICIAL INTELLIGENCE TO DRIVE SCIENTIFIC PROGRESS

We may be at a phase transition in the evolution of intelligence. By directing more AI research toward fundamental science, the immense potential of this technology can power dramatic, perhaps transformational progress on the biggest questions and significantly improve our lives.

CELEBRATE SCIENTISTS AS HEROES

Recognize the contribution to our civilization of great scientists of the past and the many brilliant researchers changing our world today. Raise their profile and prestige, and so inspire the next generation to stand on their shoulders.

FOCUS EDUCATION ON THE UNIVERSAL STORY AND USE THE POWER OF ART TO TELL IT

Thinking in terms of the **Universal Story** offers a new alternative to our fragmented, hyperspecialized approach to teaching children. There is ultimately only one field of inquiry: the **Universal Story**, which contains the history of our Universe, our planet, and our civilization, including the realm of the social sciences and humanities. This approach will make the syllabus coherent and interconnected, and the epic nature of the Story can motivate young people to contribute. Even so, once they leave school, most are unlikely to keep closely following science. But they are deeply affected by movies, television, books, music, and other forms of storytelling. Art has enormous power to express the ideas of the **Universal Story** in a comprehensible, emotionally resonant, and inspiring way.

SPARK A NEW ENLIGHTENMENT IN WHICH EVERYONE CAN CONTRIBUTE TO A SHARED CULTURE OF KNOWLEDGE

While only a few people will make the big discoveries that drive our understanding forward, we all have an important role to play in creating the conditions for such advances to take place. By working to build a society that values knowledge, rational argument, and critical thinking, we can kindle a new Enlightenment.

EUREKA MANIFESTO

WE NEED A MISSION

Every successful organization, including the largest one – our entire civilization – needs a mission

OUR MISSION

Explore and understand our Universe

WHY WE MUST EMBRACE THE MISSION

To ensure our survival, dramatically improve our lives, and build a galactic civilization

THE SIGNIFICANCE OF OUR MOMENT

It is critical that rapidly developing artificial intelligence is directed toward the Mission

HOW TO ADVANCE THE MISSION

Accelerate the Scientific Revolution and spark a new Enlightenment

POSTSCRIPT:
BEYOND THE HORIZON

We are at the very beginning of time
for the human race.

RICHARD FEYNMAN

WHEN SHE NAMED ME YURI, my mother was sending me a message. I don't think she wanted me to actually go to space – it worries her enough when I cross the street. But it is a daily reminder of who I am. Who we all are. We are an intelligent civilization, looking out beyond the horizon. Our future can be far bigger than our past.

My dream growing up was to emulate scientists like Galileo, Curie, and Hawking – to pursue the big questions and discover deep truths. After ten years as a particle physicist, though, I decided I did not have what it takes to make scientific breakthroughs. So I became a technology founder and investor. I still tried to keep up with the latest advances, but as a spectator on the sidelines, cheering the heroes on.

In recent years, my mind has increasingly returned to the idea that I could do more to support their endeavors. In 2012, my wife, Julia, and I signed Bill and Melinda Gates's and Warren Buffett's Giving Pledge, committing to fund scientific causes. That same year, we joined Sergey Brin, Priscilla Chan and Mark Zuckerberg, and Anne Wojcicki to found the Breakthrough Prize, the world's biggest prize for fundamental science and mathematics. And in 2015, with the support of Stephen Hawking, we launched the Breakthrough Initiatives, a set of space science programs investigating the big questions of life in the Universe. My hope is that, through these projects, Julia and I can contribute toward the progress of the Mission.

THE BREAKTHROUGH PRIZE

Raising the profile and prestige of scientists, so that they are recognized as the heroes they are, is one way to motivate further advances and inspire the next generation. The Breakthrough Prize is a new concept, embedding a scientific prize in a broader cultural context: a live TV event featuring the stars of science alongside the stars of entertainment and entrepreneurship.

Appendix, p. 93

Six years ago, I sat beside Julia in the hospital, holding her hand as we gazed at the grainy image on a screen: an ultrasound scan of our third daughter. It was a humbling feeling, looking at that tiny figure who seemed like she dwelled in a faraway cave, even though I knew she was right next to me. Looking at the little figure on the screen, I tried to imagine the future she would one day see in front of her.

Following my mother's footsteps, Julia wanted to send our child a message about that future. She came up with the name Romi, inspired by our neighboring galaxy Andromeda. Our larger companion, Andromeda lies two and a half million light years from our home galaxy. But it's getting closer. In around five billion years, Andromeda and the Milky Way will touch, spiraling together and merging into one. Perhaps their union might bring together the ideas, technologies, and cultures of multiple civilizations in a crucible of new discovery.

With our eyes trained on the road just in front, our clocks marking the seconds, it is hard enough for humans to imagine the next decades, let alone to comprehend cosmic timescales. But science has given us a unique time machine, allowing our minds to roam the distant past and future. And in a mere five hundred years, the Scientific Revolution has transformed our civilization beyond recognition. What could it achieve in five thousand, five million, five billion years?

The message we were sending Romi was once again to look beyond the horizon. To see her place in the galactic reaches of space, in the immense sweep of time. In the **Universal Story**.

When I think about the next generation, to which my daughters Emma, Mira, and now Romi belong, I feel full of hope for the civilization they can be part of. They or their children may be the ones to witness the next phase transition, in which we could see revolutionary changes to our bodies, minds, and culture as profound as the evolutionary leaps of the past. In the generations to come, we may begin to come of age in ways we can still barely conceive.

For the past few billion years on Earth, there has been a slow awakening. The Universe waking up. It began with the

birth of a single cell, holding a sliver of knowledge, and bloomed into a biosphere, generating better and better models of the world. It reached a new peak in humans, each beginning too as a single cell and becoming beings with minds that can reason and wonder. It evolved, with science and technology, into an intelligent civilization. And when Yuri Gagarin emerged from blue into black, that was a kind of new birth, delivering our civilization into the galaxy.

The next step is for our civilization to grow up. To mature into a mind far beyond what our own minds can dream of. Then, perhaps, our descendants will see that higher mind spread among the stars.

We have been blessed with an extraordinary gift: mind formed from matter, waking to the light of knowledge. The Mission was given to us. It is our destiny to embrace it. **To explore and understand our Universe**. To keep writing the **Universal Story**, on into the future.

APPENDIX

HOW LONG CAN WE KEEP TELLING THE STORY?

With science, we can do more than tell the **Universal Story** so far. We can tell where it's going. It is true that predicting the future is less certain than determining the past: in particular, when it comes to the future of life, minds, and knowledge themselves, we cannot trace their paths in detail, partly because of their sheer complexity and partly because they depend on discoveries yet to come. But, remarkably, fundamental physics has now reached a level where we can sketch out the broad outlines of the whole plot.

What that sketch reveals is that the Story has barely begun. The beginning of the Story, the Big Bang, was less than fourteen billion years ago. Based on our current understanding of the laws of physics, and our cosmological models that explain the state of the Universe with high precision, physicists project that the Universe will persist many trillions of times longer than the time that has so far elapsed since the Big Bang. Relatively speaking, we are living in the first instant of creation.

Our future, then, can be far bigger than our past. But it is not endless. Even if the Universe goes on forever, the **Universal Story** most likely will not. Within about a million trillion trillion years, the stars will burn out and their embers will be swept up by supermassive black holes.[17] Eventually, cosmic expansion will drag the darkened galaxies so far apart that they are permanently isolated from each other.[18] By this stage, aside from occasional stray white dwarf stars and planets, the Universe will be a cold, uneventful place. With even atoms perhaps decaying to their more fundamental constituents, there would be only an ever-thinning mist of particles wandering the vacuum, occasionally feeling the distant tug of a black hole. This is the so-called "heat death of the Universe" model: the final erosion of its islands of complexity back into the sea of chaos. Ultimately, it is hard to see how life, civilization, and the Mission itself could persist in such conditions.

The laws of physics tell us that energy is always conserved: the total energy content of the Universe remains the same. But if physicists are right that the far future will bring heat death, that means that more and more of that energy is in the form of waste heat, and less and less is available in a form that can be used to do work. And work includes thought.

Even in those bleak times, though, it is still possible that the work of understanding may continue. Freeman Dyson famously showed[19] that a system could keep processing information in such conditions, so long as it does it gradually slower and slower, using the Universe's dwindling store of useful energy at a lower and lower rate; and so long as it takes occasional breaks from processing information, during which

it can expel waste heat accumulated by its activity (if it did not do this, it would eventually burn up). In principle, it could keep pondering the big questions of the Universe forever.

However, the discovery in 1998 that the Universe is not only expanding but expanding at an accelerating rate changed that calculation. If this acceleration should continue indefinitely, then Dyson's scheme could possibly fail: it turns out that the pauses from thought may not be enough to stop any mind from burning up in its own waste heat. The theoretical physicist Brian Greene estimates[20] that this would happen in about a hundred trillion trillion trillion trillion years – after which the Universe would finally fall back to sleep. That is enough time, one would think, to reach a very deep level of understanding.

If that picture is correct, then after these last coherent chapters the **Universal Story** would fragment and then peter out, giving way to a probably infinite series of blank pages. There would be no order, only chaos. No progression, only stasis. No events of any significance. It would be a time without time. And without memory, either: for all the earlier pages of the Story would fade, too. The last echoes from the Big Bang will have long since died away, and all records of the extraordinary cosmos we see today would be lost to random drift.[21]

But that sad future only makes the present more precious. It may be that the awakened Universe has a natural span in which to find out what it is and how it got here. That span would be long – long beyond our ability to conceive of it – but bounded. All the more vital, then, to make the most of our opportunity to explore and understand. Especially since now could be the moment that our minds begin to mature to a new level.

EINSTEIN ON THE RUN

In the century preceding the Second World War, Germany had produced a significant proportion of the finest music, philosophy, and, of course, science that the world had ever known. Göttingen alone – a small university town in Lower Saxony – had been home to a remarkable number of scientific geniuses, from David Hilbert, Emmy Noether, and Bernhard Riemann in mathematics to physicists like Enrico Fermi, Paul Dirac, and Albert Einstein.

But under Nazi ideology, Einstein's most famous contributions to science – his theory of relativity, and quantum mechanics, of which he was also a pioneer – were attacked as "Jewish science": supposed perversions of common sense that were to be removed from intellectual history.[22] Today, the idea of deliberately blinding ourselves to two successful theories sounds absurd. Eventually, even the Nazis realized this, and permitted quantum physicists like Werner Heisenberg to continue to research and teach, provided they omit the names of Einstein and other Jewish scientists. The practical benefits of good science – obvious even to the worst ideologues – are indeed a powerful force for its preservation. But this episode serves to remind us that the forces of irrationality have great power, too. If a few quirks of history had gone differently, the science chauvinists could have won the argument, imposed their doctrine on much of the planet, and held scientific progress back for decades.

Scientific culture – in fact, all culture – is fragile. It is the choice of our civilization, in every generation, whether to embrace it.

DEATH BUBBLES

It is natural to most of us to think that there's not much going on in empty space. But it turns out that there could be. Many scientists believe that, at any time, a microscopic region of space could spontaneously form a "bubble," expanding in all directions at the speed of light. This would be bad news, to put it mildly. The physical laws inside the bubble would likely differ from those of the Universe we live in. This would mean that, as the bubble expanded, it would destroy all matter that it touched, including living matter. It would essentially be a baby Universe, born inside ours and devouring ours as it grew.

Although it is not known for sure whether such "death bubbles" are possible, this is a straightforward extrapolation from quantum field theory, our most successful theory of particle physics. The theory seems to be telling us that if we wait long enough, a bubble will form. Given how long the visible Universe has survived bubble-free, the probability of one reaching us in a given year is likely to be low – perhaps less than one in ten billion. But when we are thinking about the far future, such risks become critical.

The renowned physicist Ashoke Sen has suggested[23] that there might be an escape route, albeit not a permanent one. The loophole is provided by the accelerating expansion of the Universe. In 1998, astronomers discovered that all galaxies that are not strongly bound together by gravity are moving apart, ever faster. This accelerating expansion will eventually carry them beyond each other's "cosmic horizon" – in other words, they will be so far apart that even light traveling from one can never reach the other. The sad result is that they could never again communicate with each other; but the silver lining is that they could also never be swallowed by the same death bubble. So by splitting into daughter civilizations, and putting as much distance between them as possible, a civilization could "ride" the expansion of the Universe to relative safety.

Of course, another death bubble would eventually pop up within any cosmic horizon, so the remaining civilizations would need to keep replicating and parting ways. Their chances of survival then depend on how far they can travel: If they were able to move at a substantial fraction of the speed of light, they could significantly extend their long-term life expectancy.

BREAKTHROUGH INITIATIVES

Ever since I was a boy, and read Shklovsky and Sagan's *Intelligent Life in the Universe*,[24] I have seen the existence of other civilizations as one of the central questions in science. Discussing this subject with Stephen Hawking many years afterward, I found that he agreed, and in July 2015 he and I met at the Royal Society in London to launch the Breakthrough Initiatives, a series of space science programs investigating the fundamental questions of life in the Universe.

We began by announcing Breakthrough Listen, a program to reinvigorate the search for extraterrestrial intelligence. Listen is the most comprehensive search ever for evidence of technological civilizations in the Universe. It partners with some of the world's largest and most advanced telescopes, across five continents, to survey targets including one million nearby stars, the entire galactic plane and one hundred nearby galaxies at a wide range of radio and optical frequency bands.

To address the question of whether there is any – even primitive – life in the Universe, there is Breakthrough Watch: an Earth- and space-based astronomical program aiming to identify and characterize Earth-size rocky planets, with conditions potentially hospitable for life, around Alpha Centauri and other nearby stars.

In 2016, Stephen Hawking and I announced another program, Breakthrough Starshot (see Interstellar Travel, p. 91).

INTERSTELLAR TRAVEL

Sooner or later, our civilization will – will have to – push out into the cosmos. Space travel, however, is not only risky and hugely expensive, but ill-suited for humans. For robots, it could be much easier. They could withstand far greater speeds and harsher conditions. They could switch themselves off, cruising for long periods of time without need of food or entertainment.

In 1948, the great physicist and mathematician John von Neumann investigated[25] the possibility of robotic automata, which could be sent to other planets and there reproduce themselves. If these "Von Neumann machines" could mine raw materials and build more robots capable of launching into space, the spread of our civilization would become exponential. Some researchers have calculated that, even traveling at no more than one percent of the speed of light, such self-assembling robots could populate the Milky Way in about half a million years – a moment in cosmic time.

It is possible, however, that speeds greater than one percent of the speed of light will be accessible in the future. In 2016, Stephen Hawking and I launched Breakthrough Starshot, a research and engineering initiative to develop tiny space probes, the size of a microchip, that could potentially travel at up to twenty percent of the speed of light. The concept, building on work by Robert Forward in the 1970s, is to attach the probe to an ultra-thin "lightsail," which is then pushed by light pressure from a powerful source.

Starshot is an early-stage, long-term program that will need to overcome significant engineering obstacles. But if it or a similar effort works, humanity's reach into the Universe will expand significantly. Suddenly, our local cosmic neighborhood will become accessible to our machines on the timescale of a generation – rather than the tens of thousands of years that current conventional technologies, even in principle, allow.

BREAKTHROUGH PRIZE

In 2012, Julia and I, together with Sergey Brin, Priscilla Chan and Mark Zuckerberg, and Anne Wojcicki, launched the Breakthrough Prizes – the world's largest scientific awards, honoring important, primarily recent achievements in fundamental physics, life sciences, and mathematics. Each year a series of $3 million prizes are given to scientists and mathematicians at a live, internationally televised gala award ceremony in Silicon Valley that has become known as the "Oscars of science." The family of prizes also includes the Breakthrough Junior Challenge, a global science video competition for high school students.

The ceremony brings together leaders from technology, entertainment, business, and academia to celebrate science and scientists. It has featured appearances and performances from actors, musical artists, athletes, and entrepreneurs, and has been watched by millions of viewers worldwide.

REFERENCES

1. Paul Rogers, "Yuri Gagarin: The Man Who Fell to Earth," *The Independent*, October 2011. The eleven-year-old boy, John Zarnecki, would go on to become a physicist and design the science payload for the Huygens mission that landed on Titan, the exotic moon of Saturn, in 2005.

2. Freeman Dyson, *A Many-Colored Glass* (Charlottesville and London: University of Virginia Press, 2007), chapter 4.

3 Galileo Galilei, *Dialogue Concerning the Two Chief World Systems* (1632).

4. Galileo Galilei, *Dialogues Concerning Two New Sciences* (1638).

5. Ibid.

6. Simon Schaffer, "The laird of physics," *Nature* 471 (2011), 289–291. Malcolm Longair, "'...a paper ... I hold to be great guns': A Commentary on Maxwell (1865), 'A dynamical theory of the electromagnetic field,'" *Philosophical Transactions of the Royal Society A* (13 April 2015).

7. Peter Michael Harman, *The Natural Philosophy of James Clerk Maxwell* (Cambridge, U.K.: Cambridge University Press, 1998), 6. James Clerk Maxwell, *A Treatise on Electricity and Magnetism* (1873), preface.

8. Sergei Osipov et al., "The Toba supervolcano eruption caused severe tropical stratospheric ozone depletion," *Nature Communications Earth & Environment*, vol. 2 (2021), article no. 71.

9. Connor Ibbetson, "Where do people believe in conspiracy theories?" YouGov.co.uk, January 18, 2021.

10. BBC Reith Lecture, 2016.

11. James F. Kasting, NASA Ames Research Center, "Runaway and Moist Greenhouse Atmospheres and the Evolution of Earth and Venus," *Icarus* 74 (1988), 472–494.

12. Hanson, Robin, *The Great Filter – Are We Almost Past It?*, mason.gmu.edu, September 1998.

13. Carl Sagan and Ann Druyan, *Pale Blue Dot: A Vision of the Human Future in Space* (New York: Random House, 1994).

14. Poll of astrobiologists at the 2018 Breakthrough Discuss conference.

15. Katja Grace et. al, "*When Will AI Exceed Human Performance? Evidence from AI Experts*," arXiv.org, May 2018.

16. Marcus Vitruvius Pollio, *De Architectura* (c. 15 B.C.E.), vol. 9, paragraphs 9–12.

17. Brian Greene, *Until the End of Time: Mind, Matter, and Our Search for Meaning in an Evolving Universe* (New York: Alfred A. Knopf, 2020), 265.

18. Ibid, 257.

19. Freeman Dyson, "Time Without End: Physics and Biology in an Open Universe," *Reviews of Modern Physics* 51 (1979).

20. Greene, *Until the End of Time*, 277.

21. Ibid, 260ff.

22. Walter Isaacson, *Einstein: His Life and Universe* (New York: Simon & Schuster, 2007), 209, 405–410.

23. Ashoke Sen, "Riding Gravity Away from Doomsday," arXiv.org, 27 March 2015. Ashoke Sen et al., "Surviving in a Metastable de Sitter Space-Time," based on Sitender Kashyap et al., "Surviving in a Metastable de Sitter Space-Time," arXiv.org, June 2015.

24. I. S. Shklovsky and Carl Sagan, *Intelligent Life in the Universe* (San Francisco: Holden-Day, 1966).

25. John Von Neumann, *Theory of Self-Reproducing Automata* (Urbana and London: University of Illinois Press, 1966).

ABOUT THE AUTHOR

Yuri Milner is a technology investor and science philanthropist.

Born in 1961, he was named after Yuri Gagarin, who earlier that year had become the first human to reach space – a moment of deep significance for humanity that would form part of the inspiration for this book.

Yuri began his career as a theoretical physicist working in quantum field theory, but later changed fields and moved to the United States to study at the Wharton School of Business. After launching and developing a successful internet start-up, he went on to found DST Global, which has become one of the world's most successful internet investment companies. Its portfolio has included some of the biggest technology brands like Facebook, Twitter, Alibaba and Spotify.

A lifelong fascination with science, and a conviction that the future of humanity depends on its flourishing, led Yuri and his wife Julia to join the Giving Pledge, Bill and Melinda Gates and Warren Buffet's initiative whose members commit to donating half their wealth in their lifetime to philanthropic causes. Yuri and Julia have focused their donations on predominantly scientific programs. In 2012 they founded the Breakthrough Prize, a major annual science award, along with their co-founders Sergei Brin, Priscilla Chan and Mark Zuckerberg, and Ann Wojcicki. Three years later, Yuri partnered with Stephen Hawking to launch the Breakthrough Initiatives, a set of scientific programs searching for life and civilizations beyond our planet and developing the first practical technology for interstellar space flight. Yuri and Julia's foundation has also supported various humanitarian causes, including medical equipment to protect against Covid-19.

CREDITS

Illustrator: Tatiana Plakhova

Designer: Mary Shanahan

Editor: Michael Cain

ACKNOWLEDGMENTS

Nima Arkani-Hamed

Rick Klausner

Juan Maldacena

Edward Norton

Eric Schmidt

Ashoke Sen

Andrew Strominger

Jay Wacker

Special thanks to:

Adam Rosenthal

Leonid Solovyev