



Breakthrough Initiatives: Funding Fundamental Science and Innovation

“I believe that progress comes quickest when individual leadership drives collaborative ventures. It is the creativity of extraordinary people that conjures truly new ideas; social networks apply them, extend them, fill in the gaps, and nurture the next generation of geniuses.”¹

—Yuri Milner, founder, DST Global and Breakthrough Prize Foundation

Yuri Milner cultivated his passion for innovative science at an early age. Inspired by Albert Einstein and Galileo Galilei’s boldness, courage, and conviction to defy convention, Milner developed an intense drive for advancing human knowledge. He pursued his interest in theoretical physics, and worked as a doctoral student, investigating fundamental particle interactions. After he familiarized himself with Mary Meeker’s global technology research, he became convinced that the internet was the future of investment.²

In 1999, Milner founded Mail.ru Group, and under his leadership, it became one of Europe’s leading internet companies, and in 2010, Milner took the business public.³

After identifying a unique talent and interest in projecting the trajectory of technology-driven companies, Milner founded DST Global to focus on global internet investments in 2009. DST Global became one of the world’s leading technology investors and its portfolio has included some of the most prominent internet companies globally, such as Facebook, Twitter, WhatsApp, Snapchat, Airbnb, Spotify, and Alibaba, among others.

Throughout his career, Milner maintained his zeal for science. He continued to ask questions about reality and retained a profound respect for the men and women driving forward progress in fundamental physics and other sciences.⁴ Milner believed that scientific brilliance was undercapitalized, in relation to its impact on society—and he aimed to fill that funding gap with his philanthropy.

BREAKTHROUGH PRIZE

In July 2012, Yuri and his wife, Julia Milner, established the Breakthrough Prize along with a group of technology entrepreneurs including Mark Zuckerberg and Dr. Priscilla Chan, Anne Wojcicki, and Sergey Brin. Grounded by the belief that knowledge was humanity’s greatest asset

¹ “Yuri Milner,” Breakthrough Prize, https://breakthroughprize.org/Yuri_Milner (November 5, 2018).

² *Ibid.*

³ “Our History,” @mail.ru group, <https://corp.mail.ru/en/company/timeline/> (November 5, 2018).

⁴ “My Giving Pledge,” The Giving Pledge, <https://givingpledge.org/Pledger.aspx?id=246> (November 5, 2018).

and the goal of inspiring and accelerating scientific discovery, the group launched the Breakthrough Prizes—scientific awards honoring up to four recent and significant achievements in life sciences, one in fundamental physics, and one in mathematics (see **Exhibit A**).⁵ Laureates received \$3 million in prize money, the largest scientific awards in the world, with no restrictions on how they could spend the prize.

Committees of previous laureates chose Breakthrough Prize winners from candidates nominated in a process that was online and open to the public (see **Exhibit B**).⁶ Breakthrough Prize, dubbed the ‘Oscars of Science,’ hosted a live, globally televised gala awards ceremony on Nat Geo TV, Youtube, and Facebook, to celebrate the laureates’ achievements, foster greater popular support for scientific endeavors, create a stronger knowledge culture, raise the profiles of scientists globally, and inspire the next generation of scientists.⁷

To build public knowledge of their work, the prizewinners engaged in a program of lectures and discussions at a daylong symposium the day after the ceremony. Beginning in 2018, Breakthrough Prize partnered with the European Federation of Academies of Sciences and Humanities (ALLEA)⁸ and ResearchGate⁹ to directly engage with researchers and the science community to increase awareness of the opportunity to nominate great scientists and mathematicians.¹⁰ Between 2012 and 2019, Breakthrough Prize awarded over \$217 million to more than 120 scientists and teams (see **Exhibit C**).

In order to celebrate the work of promising junior researchers who have already produced important work, Breakthrough also awarded annual New Horizon prizes of \$100,000 to up to three physicists and three mathematicians. In 2015, Breakthrough Prize launched Breakthrough Junior Challenge in partnership with Khan Academy, National Geographic Channel, and Cold Spring Harbor Laboratory—a global science competition for young scientists between 13 and 18 years of age. The Junior Challenge awarded \$250,000 post-secondary scholarship to the winner, \$50,000 to their science teacher, and \$100,000 scientific laboratory to the winner’s school.

BREAKTHROUGH INITIATIVES

In July 2015, Yuri and Julia Milner launched the Breakthrough Initiatives to explore the Universe, seek scientific evidence of life beyond Earth, and encourage public debate from a

⁵ “Breakthrough Prize Opens Public Nominations for its 2019 Prizes in Fundamental Physics, Life Sciences & Mathematics, Breakthrough Prize, <https://breakthroughprize.org/News/42> (November 6, 2018).

⁶ “Rules,” Breakthrough Prize, <https://breakthroughprize.org/Rules/2> (November 6, 2018).

⁷ *Ibid.*

⁸ ALLEA brings together 59 academies in more than 40 countries, with members leading scholarly inquiry across all fields of the natural sciences, social sciences and humanities.

⁹ On the ResearchGate network, over 12 million verified scientists and mathematicians from 193 countries connect and share their research—current and past.

¹⁰ “Breakthrough Prize Opens Public Nominations for its 2019 Prizes in Fundamental Physics, Life Sciences & Mathematics, Breakthrough Prize, <https://breakthroughprize.org/News/42> (November 6, 2018).

planetary perspective.¹¹ The Breakthrough Initiatives were a long-term, multidisciplinary program of scientific research and development that explored the possible presence of extraterrestrial intelligence and life beyond Earth. As of 2018, there were three broad areas of investigation: evidence of life on extrasolar planets, evidence of extraterrestrial life, and humanity's potential reach into the cosmos.¹²

- **Breakthrough Listen** was a \$100 million program of astronomical observations in search of evidence of intelligent life beyond Earth. It was the most comprehensive, intensive, and sensitive search ever undertaken for artificial radio and optical signals in human history—including a complete survey of the 1,000,000 nearest stars, the plane and center of the galaxy, and the 100 nearest galaxies. The program secured significant time and cooperation agreements on some of the world's most powerful telescopes and utilized the most sophisticated data-analysis technologies. All data would be open to the public on a platform that enabled users to design their own search applications and make use of the data (See Exhibit D).
- **Breakthrough Watch** was a multi-million dollar astronomical program to develop Earth- and space-based technologies that could find Earth-like planets in the cosmic neighborhood, and try to establish whether they hosted life. In order to expedite the discovery and characterization of nearby Earth-like planets, Breakthrough Watch partnered with world-class scientist and engineers to develop both enhancements to Earth-based telescopes and new space-based instruments.
- **Breakthrough Starshot** was a \$100 million research and engineering program aiming to demonstrate proof of concept for a new technology, enabling ultra-light unmanned space flight at 20% of the speed of light, and to lay the foundations for a flyby mission to Alpha Centauri within a generation.
- **Breakthrough Discuss** was developed in 2016 as an annual astrobiology conference at Stanford University that brought together astronomers, astrophysicists, cosmologists, chemists, molecular biologists, geneticists, space scientists, engineers, and linguists to explore the latest research related to Breakthrough Initiatives' three areas of investigation. The conference was streamed live and was publicly available on the Breakthrough Initiatives' YouTube channel.

Recent scientific advances and breakthroughs (see Exhibit C and Exhibit D) deepened Milner's commitment to and passion for accelerating innovative science:

Because of the acceleration of progress, and the urgency of our current problems, it is tempting to regard the present as an end point, to which everything has been leading. In reality, we are at the very beginning of human history. We are only now beginning to escape the confines of our nature to out-think our pathogens,

¹¹ "About," Breakthrough Initiatives, <https://breakthroughinitiatives.org/about> (November 6, 2018).

¹² "Are We Alone," Breakthrough Initiatives, <https://breakthroughinitiatives.org/arewealone> (November 7, 2018).

outsource our memories, open-source our brains, and link them together. We have no idea where our ideas can take us. But to find out, we must invest in them now.¹³

¹³ “My Giving Pledge,” The Giving Pledge, <https://givingpledge.org/Pledger.aspx?id=246> (November 5, 2018).

Exhibit A

Defining Fundamental Sciences

Fundamental sciences refer to the sciences that ask big questions and seek the deepest explanations.

Fundamental sciences that have been recognized by the Breakthrough Prize include:

- Mathematics
- Particle physics
- Cosmology
- Genetics
- Molecular biology
- Neurology

Fundamental questions that Breakthrough Prizes explore include, but are not limited to:

- What is the Universe made of?
- Is there life, intelligent or otherwise, elsewhere in the Universe
- How did life begin?
- How can matter think?
- How much is knowable?

Source: Breakthrough Prize

Exhibit B

Breakthrough Prize Rules

Principle

The Breakthrough Prizes in Life Sciences are awarded annually for accomplishments in life sciences broadly defined.

Prizes

Each year, Breakthrough Prize awards up to four prizes in life sciences, one in fundamental physics, and one in mathematics. Each prize comes with a \$3 million award.

Nominations

- Anyone can nominate a candidate at the online nominations page during the open nominations period.
- Self-nominations are not allowed.
- A valid nomination will have basic biographical information on the nominee and nominator and at least one third-party letter of recommendation.
- Candidate citations—up to 10—from a specified academic publishing database are required.
- During the nominations period please see the nominations form at breakthroughprize.org/Nominations.

Selection Committee

- Past recipients of the prizes are invited to serve on the Selection Committee to select recipients of future prizes.

Source: “Rules,” Breakthrough Prize, <https://breakthroughprize.org/Rules/2> (November 6, 2018).

Exhibit C Breakthrough Prize Winners 2019

The Breakthrough Prize recognized achievements in the life sciences, fundamental physics, and mathematics—the disciplines that ask the biggest questions and find the deepest explanations.

In 2019, a total of \$22 million was awarded for breakthroughs including:

2019 Breakthrough Prize in Life Science

- **C. Frank Bennett and Adrian R. Krainer:** For the development of an effective antisense oligonucleotide therapy—Spinraza—for children with the neurodegenerative disease spinal muscular atrophy, a deadly infant disease.
- **Angelika Amon:** For determining the consequences of aneuploidy, an abnormal chromosome number resulting from chromosome mis-segregation that is implicated in almost all cancers and can otherwise wreak havoc in the human body.
- **Xiaowei Zhuang:** For discovering hidden structures in cells by developing super-resolution imaging—a method that transcends the fundamental spatial resolution limit of light microscopy.
- **Zhijian “James” Chen:** For elucidating how DNA triggers immune and autoimmune responses from the interior of a cell through the discovery of the DNA-sensing enzyme cGAS, with implications for cancer and autoimmune diseases.

2019 Breakthrough Prize in Fundamental Physics

- **Charles Kane and Eugene Mele:** For new ideas about topology and symmetry in physics, including the discovery of a new class of electronic materials that simultaneously conduct and resist electricity and could prove transformative for quantum computing.

2019 Breakthrough Prize in Mathematics

- **Vincent Lafforgue:** For groundbreaking contributions to several areas of mathematics, in particular to the Langlands program in the function field case.

Source: “Winners of the 2019 Breakthrough Prize in Life Sciences, Fundamental Physics and Mathematics Announced,” Breakthrough Prize, <https://breakthroughprize.org/News/47> (November 6, 2018).

Exhibit D Breakthrough Listen

Breakthrough Listen was launched in 2015 at London’s historic Royal Society, by Yuri Milner, Stephen Hawking, and Martin Rees, among others. They presented a \$100 million international program of radio and optical astronomy searching for evidence of intelligent life among the nearest 1,000,000 stars, the galactic center, and the 100 nearest galaxies.

Thanks to NASA’s Kepler mission and other ventures, the field of astrobiology matured rapidly. The founders believed that the universe was much more welcoming to life than previously assumed: statistically, virtually all stars were now thought to host at least one planet, and 30% of stars were thought to have Earth-like planets in their ‘habitable zone,’ where liquid water could exist. Meanwhile, technical advances expanded search capabilities:

- Signal processing capabilities doubled every 18 months. That's a million-fold improvement over 30 years.
- This improvement, combined with advances in telescope, feed, receiver, and computing technology meant the power of searches for extraterrestrial intelligence (SETI) roughly doubled every year.

Scope of Program

- Study the 1,000,000 nearest stars.
- Complete an unprecedented survey of the entire Milky Way.
- Complete a comprehensive survey of the galactic center.
- Observe the 100 nearest galaxies.

Program Performance

- 50 times more sensitive than previous searches.
- 100 times faster than previous searches.
- 10 times greater sky coverage than previous searches.
- 5 times wider radio spectrum than previous searches.

The program searched for two kinds of signal: radio and optical (visible light). The radio surveys use the world’s biggest radio telescopes. Breakthrough Listen designed and built specialized search instruments (signal processing equipment) that processed signals that emerge from the telescope receivers.

Instruments

- 100 meter Robert C. Byrd Green Bank Telescope
- 65 meter Diameter Parkes Telescope
- Automated Planet Finder Telescope at Lick Observatory

Cooperation Agreements

Breakthrough Listen developed partnerships with the FAST telescope in China, the world's largest moveable radio dish, the new MeerKAT telescope, which will be part of the vast Square Kilometre Array spanning South Africa and Australia; and with the famous Jodrell Bank instrument in the U.K, to share data and coordinate activities and rapid follow-up observations of possible signals.

Data Analysis

- Breakthrough Listen partnered with the University of California Berkeley data processing team.

Results

In January 2016, Breakthrough Listen was launched. It has since provided major technical upgrades including compression algorithms to manage and store the vast troves of data produced by the observations.

As of November 2018, there had been no confirmed artificial signals. Breakthrough Listen, however, had produced some important astronomical results, including the identification of new Fast Radio Bursts (FRBs)—the distant, immensely powerful pulses of radiation whose source is still a mystery to astrophysics.

In August 2017, the Listen program at the Green Bank Telescope detected 15 new bursts from FRB121102, the only FRB known to repeat. In March 2018, the Parkes telescope discovered a new source, FRB180301—aided by innovative machine learning algorithms developed by the Breakthrough Listen team at UC Berkeley. In December 2017, Breakthrough Listen also performed radio observations on 'Oumuamua, the first interstellar object to be spotted passing through the solar system, followed by observations of “retrograde” asteroid 2015 BZ509, which could originate from another star system.

Source: “Breakthrough Listen,” Breakthrough Initiatives, <https://breakthroughinitiatives.org/initiative/1> (November 12, 2018).