

The *Breakthrough Listen* Initiative is a ten-year program that represents humanity's most significant effort to-date to quantify the distribution of advanced life in the Universe.

The *Breakthrough Listen* Project

- Searching for signatures of technology as a proxy for intelligence
- Detailed census of thousands of nearby stars
- Broad survey of millions more stars, the plane of the Milky Way, and other galaxies
- Wide-field radio and optical surveys
- Uses the world's most powerful observing facilities:
 - 100-meter Green Bank Telescope - the largest steerable radio telescope in the world
 - 64-meter Parkes Telescope in Australia
 - Automated Planet Finder telescope in California
- Other partners:
 - Jodrell Bank Centre for Astrophysics, home of the Lovell Telescope and e-MERLIN
 - China's FAST telescope, the world's largest single dish
- Under development:
 - Murchison Widefield Array, Australia
 - Irish/UK Low Frequency Array (LOFAR) International Stations
 - PANO-SETI (UCSD / Harvard)
 - VERITAS Pulsed optical SETI
 - South African MeerKAT Array

Cutting-edge capabilities

- Petascale storage and computing
- Terabits / second raw data rates
- Equivalent to tuning to billions of radio stations, for millions of targets
- Generating image-like data arrays (intensity as a function of frequency and time) that are amenable to advanced data analytics and deep learning approaches
- Public data enables contributions from scientists worldwide, and outside experts.
- Computing on-site, at UC Berkeley and partner universities, and in the cloud
- Driving discovery in other areas of astronomy (e.g. fast radio bursts)
- Collaboration with SETI@HOME allows the entire world to participate

Challenges

- Enormous data volumes (challenging to store and analyze, and to make available to the public)
- Sifting through interference from human technology to find signals of interest (requires new approaches to automated detection and classification)

The *Breakthrough Listen* Initiative is sponsored by the Breakthrough Initiatives via a sponsored research agreement with the University of California, Berkeley. www.breakthroughinitiatives.org



BREAKTHROUGH LISTEN

The *Breakthrough Listen Initiative* is a ten-year program that represents humanity's most significant effort to date to quantify the distribution of advanced life in the Universe. *Listen* uses the world's most powerful observing facilities (including the Green Bank Telescope - the largest steerable radio telescope in the world) to search for signatures of technology. Additional *Listen* facilities include the 64-meter Parkes dish in Australia, the South African MeerKAT array, and the Automated Planet Finder telescope in California. *Listen* is also partnering with the Jodrell Bank Observatory, home to the 76-meter Lovell Telescope, and China's FAST telescope, the world's largest single dish. Partnerships are under development with Cherenkov telescopes (arrays of large optical detectors) such as VERITAS, as well as the Murchison Widefield Array, which, along with MeerKAT, is a precursor instrument for the international Square Kilometre Array.

The first small steps in the search for extraterrestrial intelligence were undertaken almost 60 years ago. In the intervening decades, we have learned that our Galaxy is full of planets with both the conditions and the ingredients for life. This new knowledge, combined with the astonishing increase in computer processing and storage capabilities, and the power of modern data analytics, are enabling *Breakthrough Listen* to take a giant leap forward in our quest to answer the question: Are we alone?

The *Listen* instruments at the Green Bank and Parkes telescopes process hundreds of gigabits per second of data. The system on the MeerKAT array will process nearly 5 terabits per second. *Listen* performs the equivalent of tuning to billions of radio stations at once, using some of humanity's most powerful antennas. The project is undertaking a detailed census of hundreds of nearby stars, in addition to casting a wider net across millions more stars, the entire plane of our Milky Way Galaxy, and additional galaxies beyond.

The cutting-edge instrumentation and techniques developed for *Listen* are also making their mark in other areas of astronomy research. The *Listen* science team at the University of California, Berkeley, recently used data from Green Bank to reveal fascinating insights into powerful and mysterious "fast radio bursts" from the distant Universe.

Listen makes huge amounts of data publicly available, enabling all of the world's scientists to contribute. Some of the greatest discoveries in astronomy have come from re-analysis of archival data, often by independent scientists. Public data also enables involvement from non-astronomers with technical expertise, such as experts in deep learning, signal processing, and big data analytics.

One of *Listen*'s major challenges is to sift through the haystack of interference from human technology (satellites, cellphones, airplanes, and so on), to find the needle that might be a candidate for our first message from an alien civilization. But just as the development of the first telescope technology 400 years ago enabled Galileo to understand that there existed worlds beyond our own, technology is once again driving forward the frontiers of discovery as we seek to understand if Earth is one jewel in a vast, sterile Universe, or if inexorable forces drive matter to eventually become minds. We are at the brink of answering one of the most profound questions in science.

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