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Fujitsu Limited
Nagoya University, Tokai National Higher Education and Research System
Japan Agency for Marine-Earth Science and Technology
National Institute of Information and Communications Technology

Fujitsu, Nagoya University, JAMSTEC and NICT develop technology to automatically optimize parameters for solar energetic particle simulations

Helping protect astronauts from radiation risks while promoting the use of satellite data and the creation of future lunar industries

Kawasaki, Nagoya, Yokosuka and Tokyo, Japan, October 21, 2026 — Fujitsu Limited [1] (Fujitsu), Nagoya University, Tokai National Higher Education and Research System [2] (Nagoya University), the Japan Agency for Marine-Earth Science and Technology [3] (JAMSTEC), and the National Institute of Information and Communications Technology [4] (NICT), together with their research partners in Japan and Portugal [5], today announced the development of the world's first technology [6] that uses observational data from five spacecraft to objectively, reproducibly and automatically determine the parameters of physical simulations used to calculate the arrival of solar energetic particles (SEPs) [7], improving the simulations' accuracy. SEPs can expose astronauts to radiation and cause satellite malfunctions. The results were published in the journal Scientific Reports [8].

Applying this technology to SEP arrival prediction is expected to help reduce satellite failures and promote the use of satellite data. By reducing radiation exposure risks, it can also help ensure astronaut safety and, in the future, contribute to the creation of new industries associated with lunar base activities.

Because SEPs are electrically charged and scatter as they travel along magnetic field lines extending from the Sun, predicting their arrival is extremely difficult. Until now, experts have determined parameter values through experience and trial and error so that simulations could reproduce observations of past events. This approach, however, made it difficult to objectively justify the values and reproduce the results using the same procedure. The research group therefore automated parameter setting using black-box optimization [9]. Specifically, the group succeeded in automatically setting 19 parameters [10] for a physical simulation that calculates SEP intensities and arrival times, minimizing discrepancies between the simulation and observations made by five spacecraft, including BepiColombo, the Mercury exploration mission conducted as a joint European-Japanese project. At the core of the technology is the Fujitsu Solar Energetic particle Intelligent Tuning and Evaluation Network (SEITEN) [11], developed by Fujitsu. SEITEN links SUSANOO [12], a magnetohydrodynamic (MHD) simulation [13] developed by the Institute for Space-Earth Environmental Research at Nagoya University and operated by NICT, with SEPIF [14], a particle acceleration and transport model developed by JAMSTEC. Using black-box optimization, it automatically determines parameters related to particle acceleration and transport. Interplanetary scintillation (IPS) [12] observational data from Nagoya University's Institute for Space-Earth Environmental Research were also used to select the MHD simulation settings.

Using observational data from multiple spacecraft, the research group automated the complex task of setting parameters representing factors such as the strength of particle scattering, while also enabling estimation of their spatial distribution [15]. This represents an important step toward the practical application of technology for accurately predicting SEP intensities and arrival times.

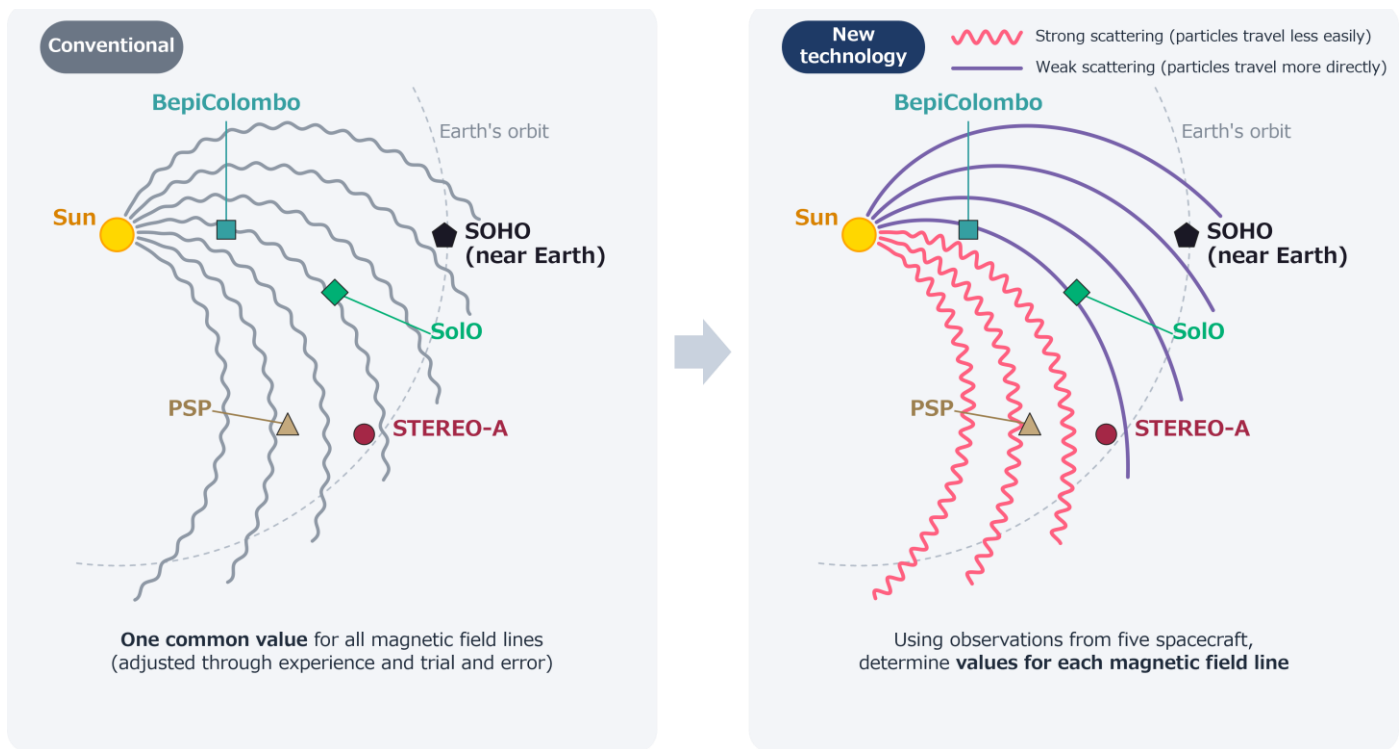


Figure 1. Comparison between conventional parameter determination and the new technology. This schematic views the Sun from above its north pole. The spiraling lines extending from the Sun represent magnetic field lines, and the symbols show the positions of the five spacecraft on October 10, 2021 (PSP: Parker Solar Probe; SolO: Solar Orbiter).

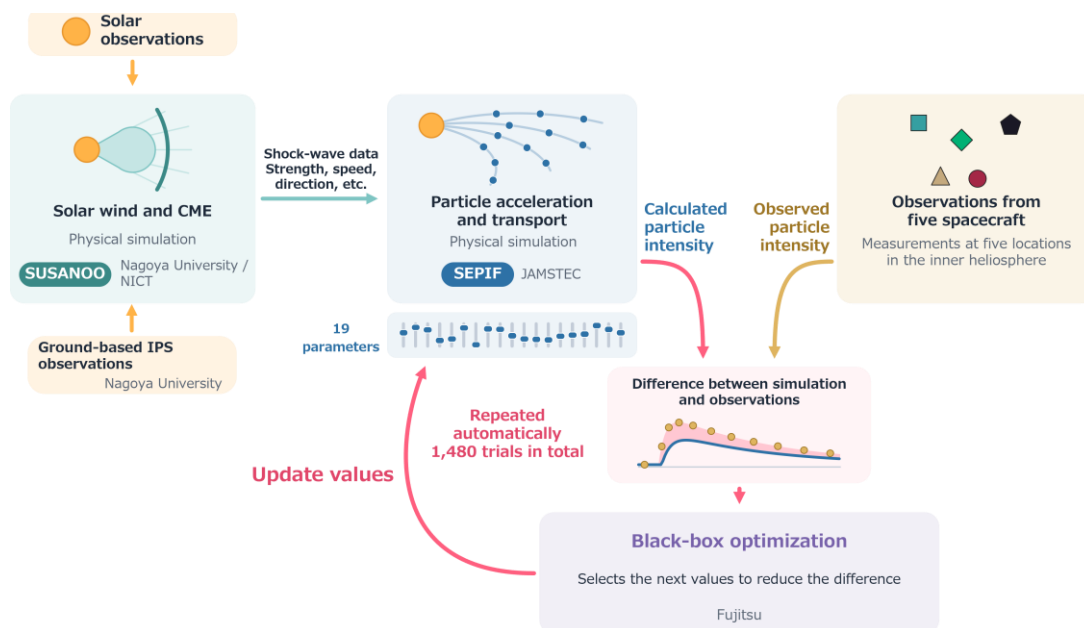


Figure 2. Overview of the technology. Two physical simulations are linked, and mathematical optimization automatically and repeatedly updates parameter values to reduce discrepancies between the calculations and observations from the five spacecraft.

Background

The sphere of human activity is expanding from Earth orbit to the lunar surface. Japan's Basic Plan on Space Policy, approved by the Cabinet in June 2023, calls for the phased development of power, communications, positioning and other systems to support sustainable human activity on the Moon and aims to create new industries. International initiatives for human lunar activity, including the Artemis program in which Japan participates, are also progressing. At the same time, radiation arriving from the Sun, including SEPs, is one of the factors that threaten the safety of such space activities.

Solar flares and coronal mass ejections (CMEs) [16] can accelerate particles such as protons and electrons to speeds reaching several tens of percent of the speed of light and release them into interplanetary space. The resulting SEPs can cause equipment failures and malfunctions in satellites and pose radiation exposure risks to astronauts. As lunar activity becomes more extensive, it is therefore important to determine in advance when, where and how intensely SEPs will arrive. One promising way to predict their arrival is through simulations that calculate particle acceleration and transport based on physical laws. However, these simulations include many values, or free parameters, that

cannot be measured directly from observations. Representative examples include injection efficiency, the fraction of particles ahead of a shock wave that enter the acceleration process, and mean free path, a measure of the distance particles travel along a magnetic field line before being scattered. Even slight changes in these values can alter predicted particle intensities by orders of magnitude.

The parameters must therefore be adjusted to match past observational data. Conventional adjustment methods, however, depend on experts' experience and trial and error, making it difficult to objectively justify the values or reproduce them using the same procedure. In addition, the number of parameters has often been kept small enough to allow manual adjustment. As a result, values that are thought to differ by magnetic field line could not be determined for each field line from observational data. Attempting to determine separate values for each line increases the number of parameters. Simply testing 10 values for each of the 19 parameters addressed in this study would produce 10^{19} combinations. Since manually searching for a combination that simultaneously matches observations from multiple distant locations is impractical, a mechanism was needed to search objectively and reproducibly based on observational data.

Future Plans

Fujitsu, Nagoya University, JAMSTEC and NICT will further advance this technology to realize more reliable prediction capabilities. By enabling earlier assessment of radiation exposure and satellite failure risks, the organizations aim to contribute to improved safety in lunar industries such as construction and transportation, as well as in sustainable human activities on the Moon.

Trademark information

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Notes

1. Fujitsu Limited:
Head office: Kawasaki, Kanagawa, Japan. Representative Director and CEO: Takahito Tokita.
2. Nagoya University, Tokai National Higher Education and Research System:
Location: Nagoya, Aichi, Japan. President: Naoshi Sugiyama. The research was conducted with the university's Institute for Space-Earth Environmental Research (ISEE).
3. Japan Agency for Marine-Earth Science and Technology:
Location: Yokosuka, Kanagawa, Japan. President: Tomohiko Kawamura.
4. National Institute of Information and Communications Technology:
Location: Koganei, Tokyo, Japan. President: Hideo Ohno.
5. Research participants:
In addition to Fujitsu, Nagoya University's ISEE, JAMSTEC and NICT, the research involved the Japan Aerospace Exploration Agency (JAXA), the Laboratory of Instrumentation and Experimental Particle Physics (LIP) and the University of Lisbon, both in Portugal.
6. Basis for the "world's first" claim (according to Fujitsu research, as of October 2026):
The novelty of this technology lies in its simultaneous fulfillment of the following three conditions:
(1) It uses simultaneous observations from multiple spacecraft as constraints, enabling the identification of parameters that vary by direction.
(2) It couples an MHD simulation with a particle acceleration and transport model, enabling the strength and shape of shocks generated by coronal mass ejections (CMEs) to be reflected in particle acceleration calculations.
(3) It automatically determines parameters related to particle acceleration and transport through black-box optimization, without manual intervention during the search.
7. Solar energetic particles (SEPs): High-energy protons and electrons accelerated by solar flares and CMEs and released into interplanetary space.
This research focused on protons.
8. Paper information:
Hiroyuki Tako Ishikawa et al., "Automated Optimization of Solar Energetic Particle Acceleration and Transport Parameters Against Five-Spacecraft Observations of the 9 October 2021 Event," *Scientific Reports* (2026). DOI: 10.1038/s41598-026-70869-9. Published October 20, 2026.
9. Black-box optimization:
A method that searches for good solutions through repeated trials and evaluations without assuming the internal structure of the objective function. This technology combines broad exploration using a quasi-Monte Carlo method (Sobol' sequence) with focused exploration using TPE (Tree-structured Parzen Estimator), a form of Bayesian optimization. The open-source optimization framework Optuna was used for implementation.
10. Automatic setting of 19 parameters:
The 19 parameters comprise seven mean free path values, one for each magnetic field line, representing scattering strength, and 12 injection efficiency values, one for each direction, representing the fraction of particles that enter the acceleration process at a shock wave. Because each trial requires a complete, time-consuming simulation, the number of trials is limited. The two-stage search described in Note 9 narrowed the candidates through 1,000 broad trials and 480 focused trials in promising regions, for a total of 1,480 trials. Applied to an SEP event that occurred on October 9, 2021 and was simultaneously observed by five spacecraft, the method broadly reproduced the onset, rise and peak of the particle intensity at all five spacecraft. The procedure and evaluation criteria were defined in advance, and independent repetitions confirmed the same overall trend.

11. **Fujitsu Solar Energetic particle Intelligent Tuning and Evaluation Network (SEITEN):**
The name SEITEN is derived from the Japanese word *seiten*, meaning “clear sky.” It reflects two aspirations: to clear up the behavior of SEPs, and to help secure the all-clear, the state in which they pose no threat.
12. **SUSANOO:**
An acronym for Space-weather-forecast-Usable System Anchored by Numerical Operations and Observations. Developed by Nagoya University’s ISEE, SUSANOO is an MHD simulation that calculates the propagation of solar wind and CMEs through interplanetary space. NICT operates the system and uses it for daily arrival predictions of solar-wind disturbances in space weather forecasting. Interplanetary scintillation (IPS) is the twinkling of radio waves from distant radio sources, caused by irregularities in the density of the solar wind that scatter the waves. The twinkling becomes stronger when a CME crosses the path of the radio waves. In this research, multiple SUSANOO-CME simulations were conducted with varying CME magnetic flux. IPS observables synthesized from the simulation results were compared with actual IPS observations made by Nagoya University’s ISEE. The case most consistent with IPS observations and another case most consistent with the CME arrival time at Earth were used for SEP acceleration and transport calculations.
13. **MHD simulation:**
A computational method that treats plasma as a fluid and computes its behavior including interactions with magnetic fields.
14. **SEPIF:**
An acronym for Solar Energetic Particle Injection and Focused transport model. Developed by JAMSTEC, SEPIF calculates particle acceleration at shock waves and transport along magnetic field lines.
15. **Estimation of the spatial distribution of parameters and the five spacecraft:**
Because the shape and strength of a shock wave differ by direction as viewed from the Sun, the strength of particle scattering is also expected to vary by direction. A single observation point cannot distinguish these differences, so parameters previously had to be assumed spatially uniform. The new technology searched for solutions that simultaneously satisfied observations from five spacecraft located 0.33 to 1.0 astronomical units from the Sun (1 astronomical unit, the average Earth-Sun distance, is about 150 million km) and spread across approximately 50 degrees as viewed from the Sun, allowing directional parameter distributions to be estimated. The researchers also confirmed that assuming a uniform mean free path regardless of direction increased error and prevented the simultaneous reproduction of observations from all five spacecraft. The five spacecraft, each equipped with energetic particle instruments, are BepiColombo (a joint ESA-JAXA mission to Mercury), Solar Orbiter (a joint ESA-NASA mission), Parker Solar Probe (a NASA mission), STEREO-A (a NASA mission) and SOHO (a joint ESA-NASA mission).
16. **Coronal mass ejection (CME):**
A large-scale eruption of plasma from the solar atmosphere. A fast CME can drive a shock wave at its leading edge that accelerates particles.

Related Links

- Automated Optimization of Solar Energetic Particle Acceleration and Transport Parameters Against Five-Spacecraft Observations of the 9 October 2021 Event:
<https://doi.org/10.1038/s41598-026-70869-9>
- Human-Interpretable SEP Event Prediction Using White-Box Explainable AI:
<https://doi.org/10.1029/2025SW004635>
- Fujitsu and Tokai National Higher Education and Research System develop space weather prediction capabilities technology leveraging AI:
<https://global.fujitsu/en-global/pr/news/2026/01/28-01>
- Fujitsu and Tokai National Higher Education and Research System collaborate on AI-based space weather research:
<https://info.archives.global.fujitsu/global/about/resources/news/press-releases/2024/0314-01.html>
- Nagoya University Institute for Space-Earth Environmental Research:
<https://www.isee.nagoya-u.ac.jp/en/>
- JAMSTEC:
<https://www.jamstec.go.jp/e/>
- NICT:
<https://www.nict.go.jp/en/>
- JAXA:
<https://global.jaxa.jp/>
- LIP:
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About Nagoya University, Tokai National Higher Education and Research System

Boasting a free and vibrant academic culture, Nagoya University has produced prominent leaders in Japanese industry through its globally renowned research and achievements, which have led to the awarding of Nobel Prizes to six Nagoya University scientists.

About Japan Agency for Marine-Earth Science and Technology

JAMSTEC is engaged in activities to contribute broadly to the improvement of science and technology, the development of academic research, and the understanding of the Earth and life through ocean research in Japan, a nation of oceans.

JAMSTEC promotes research and studies on the understanding of the global environment, the utilization of ocean resources, and seismic and volcanic activities. In addition, we create new value from the data obtained through our research activities to contribute to the needs of society and the economy.

About National Institute of Information and Communications Technology

The National Institute of Information and Communications Technology (NICT) is Japan's sole National Research and Development Agency specializing in the field of information and communications technology and is charged with promoting the ICT sector as well as research and development in ICT, which drives economic growth and creates an affluent, safe and secure society.

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