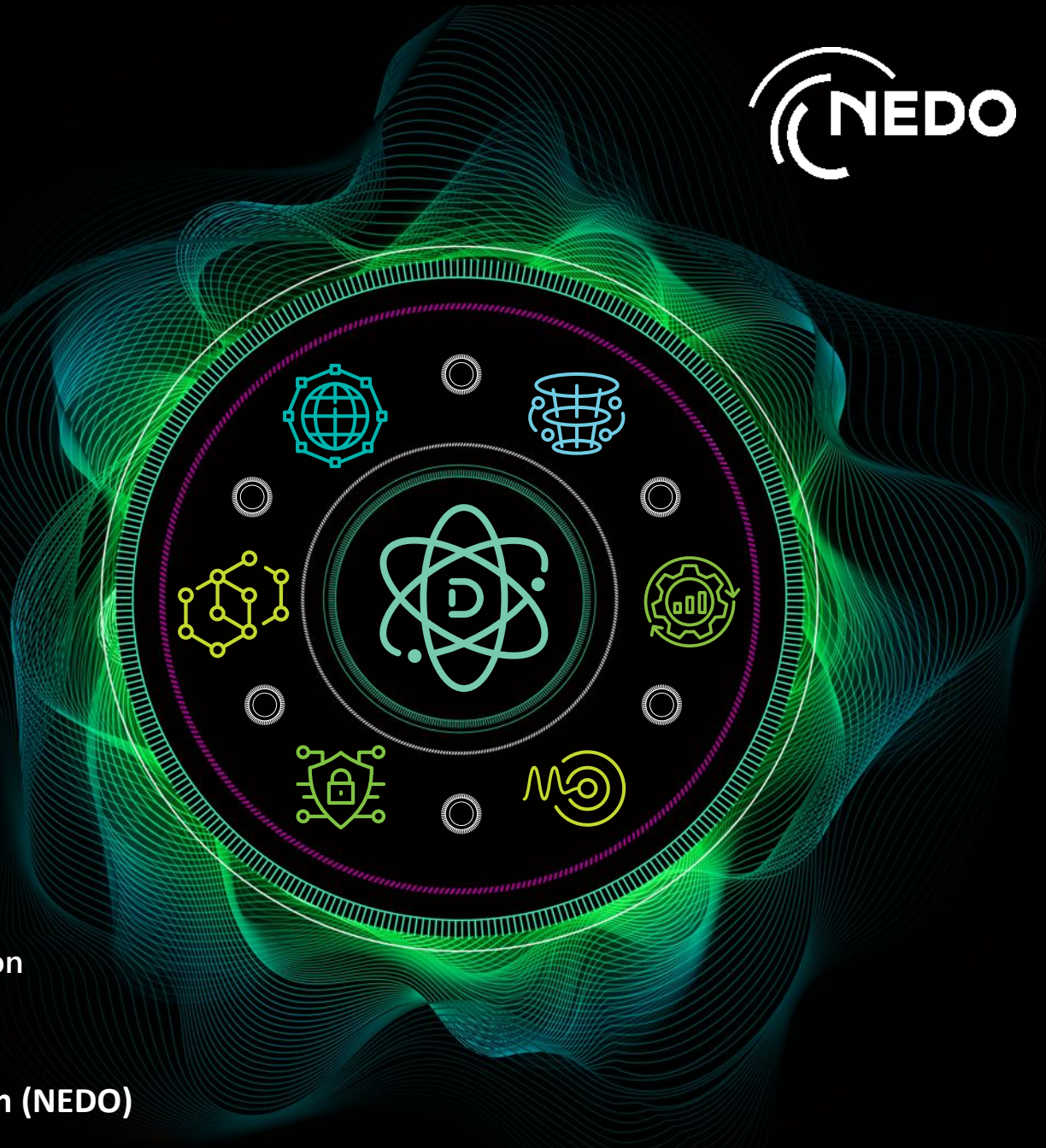
Quantum Computing Use Cases

Extreme environment simulation



Promotion of SDGs with Quantum Technology

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New Energy and Industrial Technology Development Organization (NEDO)

極限環境シミュレーション
Extreme environment simulation



ユースケース概要 **Use Case Overview**	宇宙空間、他惑星における居住設備や空調・水システムの設計シミュレーション Design simulation of living facilities, air conditioning, and water systems in outer space and on other planets.
解決できる課題と効果 **Issues to be addressed and their effects**	宇宙への移住が可能となり、地球での資源使用量が減少 Migration to space has become possible, leading to a decrease in resource usage on Earth.
量子技術の貢献 **Contributions of quantum technology**	極限環境が人や物質に与える中長期的影響をシミュレーション Simulating the medium to long-term effects of extreme environments on people and materials.

実現予想時期 **Expected realization period**	(Year)2035～2040
産業分類 **Industry classification**	ユーティリティ・通信 Utilities・Communications
関連するQRAMI階層 **Related QRAMI layers**	事業層 Business layer
関連する量子技術 **Related quantum technologies**	量子コンピュータ(FTQC) Quantum Computer(FTQC)

新規性 **Novelty**	大きな革新 Significant innovation
達成難易度 **Difficulty of achievement**	非常に困難 Very Difficult
社会貢献度 **Social contribution level**	社会全体に貢献 Contributions to society as a whole
市場規模 **Market size**	見積困難 Difficult to estimate

Detail

Extreme environment simulation

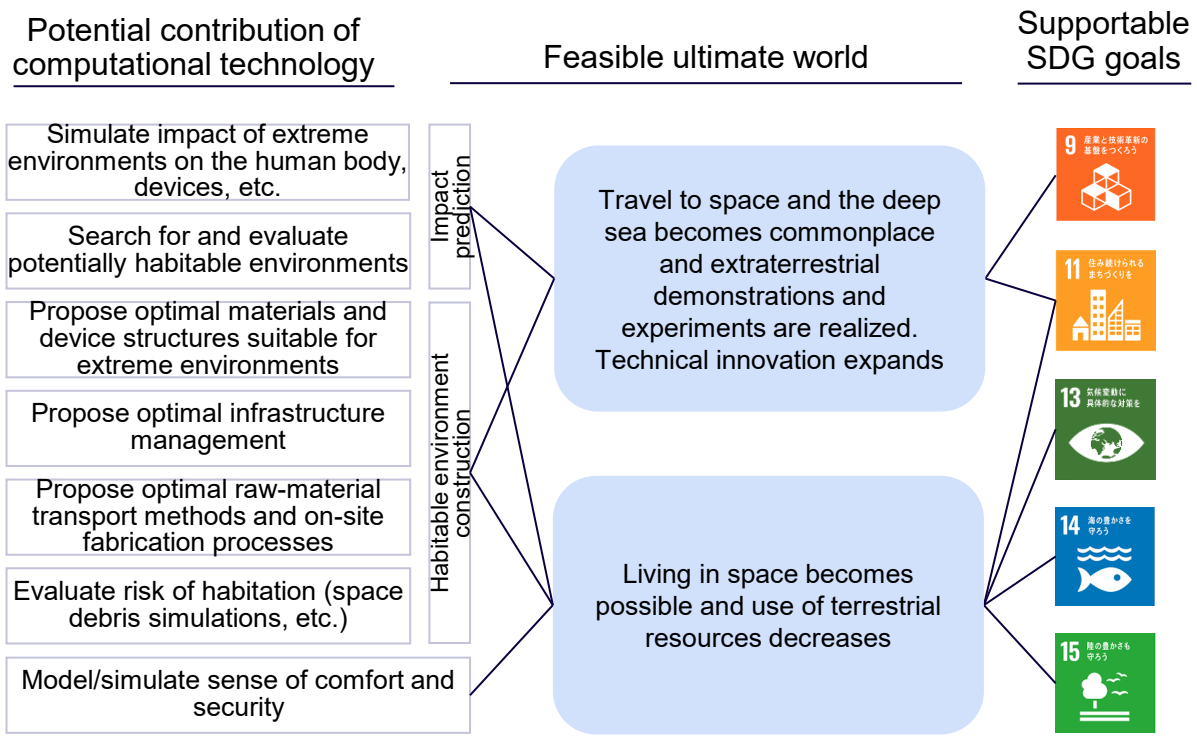
- Even the deep sea and outer space will become comfortable living space through advances in extreme-environment simulations and sciences researching a sense of comfort and security.



54.17 million people

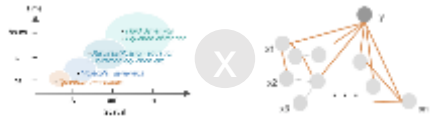
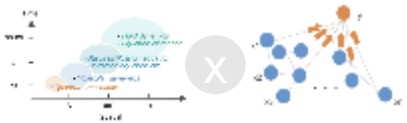
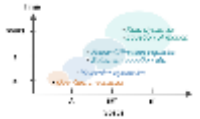
Population that can live in space

With current technologies, methods of food transport, self-sufficiency, etc. for habitats and air-conditioning/water systems in outer space and other planets have yet to be established. Such habitation will become possible provided a certain amount of funding is available by enabling extreme-environment simulations and material design.



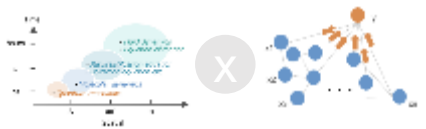
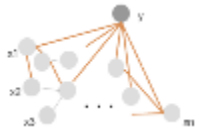
Roadmap

Extreme environment simulation

Process (1/2)		Necessary R&D and business development	Quantum-computer scope of contribution and future development issues	
Simulation of extreme environments become possible	Establish/select environmental models	■ Construction of extreme-environment models (Construct highly precise models through time-series environmental changes, interactions between all environmental systems as opposed to just a single environment, and high-resolution parameters. The need for large-scale data processing is assumed.) → Formalize interactions precisely by combining quantum-chemical and molecular-dynamics calculations	Construct precise models by combining theoretical and causal models 	■ Accelerate quantum chemical calculations ■ Developing algorithms to solve MD equations quickly ■ Expand the scope of applying quantum computers to statistical analysis including linear regression analysis (develop techniques to expand the application range beyond existing algorithms)
	Collect existing data in various extreme environments	■ Technologies for obtaining existing parameter data in various extreme environments difficult for humans to get to (probes, observation technology, etc.) ■ Technologies for obtaining high-resolution data (microorganism classification, water-stirring effects, etc.)	-	■ None in particular
	Establish computational technology	■ Establish digital twins to simulate impact (including mid-to-long term effects) of extreme environments on people and materials (including impact on materials and devices, impact on human health (radiation, low gravity, etc.), environmental impact on existing habitats, etc.) ■ Establish simulation techniques to search for potentially habitable environments such as new planets (requires several years of calculations with current supercomputers)	Solve union of a theoretical model and causal model 	■ Develop techniques that enable an integrated approach combining theoretical and causal models instead of solving individual models separately
Construction of habitable environments in extreme environments	Develop optimal materials/systems for extreme environments	■ Materials resistant to ultraviolet rays, ozone, etc. (for construction), device structure (power-generation devices, storage batteries, communications/medical devices, etc.) ■ Optimization of infrastructure management systems (optimization of resource generation/management systems for air, water, energy, etc., optimization of agricultural and medical systems) → High-speed calculation of optimal materials and synthesizing/manufacturing processes through quantum chemical calculations, fluid calculations, etc.		■ Accelerate quantum chemical calculations ■ Developing algorithms to solve MD equations quickly ■ Nonlinear equations (develop algorithms to solve Navier–Stokes equations, etc. at high speed)
	Initiate work on constructing habitable environments in extreme environments	■ Development of AI robots, etc. resistant to extreme environments and capable of remote unmanned work ■ Establish an approach to reducing material-transport costs (e.g. optimal design of materials/structures for space elevators, achieve “local production for local consumption” through space 3D printers)	-	■ None in particular

Roadmap

Extreme environment simulation

Process (2/2)		Necessary R&D and business development	Quantum-computer scope of contribution and future development issues	
Construction of habitable environments in extreme environments	Check risk of extreme-environment habitats	■ Verify habitat safety by simulations Example: Analyze space-debris orbits (there are examples of doing so using supercomputers) ■ Conduct long-term simulations of physical/psychological effects of extreme-environment living to show whether long-term risks are absent or can be avoided (study effects of radiation and low gravity on health and effects of raising children in an extreme environment from a social perspective, etc.)	Solve union of a theoretical model and causal model 	■ Make orbital analysis calculations more precise and faster ■ Develop techniques that enable an integrated approach combining theoretical and causal models instead of solving individual models separately
Advances in comfort and security sciences	Establish/select comfort/security models	■ Although general models of the feeling of comfort already exist, more precise models and modeling of feelings other than comfort are needed to assist people living in extreme environments. →Extract more parameters, perform linear analysis on datasets with a large number of people, and optimize functions.		■ Expand base of linear regression analysis (develop techniques to expand the application range beyond existing algorithms)
	Set up development environment using calculations	■ While similar to the above examples, the idea here is to establish a digital twin that can completely simulate on a computer how a person might feel in a certain situation (like performing an experiment one last time)	Solve forward problems in causal models 	■ Within those models, identify computational tasks difficult to solve by a classical approach ■ Develop algorithms to efficiently solve those tasks
	Economic/social motivations that encourage extreme-environment habitats	■ Design national encouragement measures and incentives as in UAE ■ Study questions like “Who owns land and resources in space?” from a space ethics perspective		■ None in particular

Roadmap

Extreme environment simulation

Process (1/2)

Necessary steps

Items related to quantum computers

2024 | 2025-2030 | 2030-2040 | Beyond 2040

Simulation of extreme environments become possible

Establish/select environmental models

- Verify the feasibility and business potential of identifying model functions
- Accelerate quantum chemical calculations
- Develop algorithms to solve molecular dynamics equations at high speed
- Expand the scope of applying quantum computers to statistical analysis including linear regression analysis
- Formalize impact of extreme environments on the human body, devices, etc. based on quantum chemical calculations
- Refine models while acquiring high-resolution data

Collect existing data in various extreme environments

- Existing development under current conditions, collection of measurement data, analysis
- Establish technologies for obtaining data in various extreme environments difficult for humans to get to (probes, observation technology, etc.)
- Establish technologies for obtaining high-resolution data (microorganism classification, water-stirring effects, etc.)

Construction of habitable environments in extreme environments

Establish computational technology

- Verify the feasibility and business potential of accelerating calculations using quantum computers
- Develop techniques that enable an integrated approach combining theoretical and causal models
- Establish solutions to the effects of extreme environments on people and devices combining prediction algorithms and quantum computing
- Establish simulation techniques to search for potentially habitable environments (new planets, etc.) at high speed

Develop optimal materials/systems for extreme environments

- Accelerate quantum chemical calculations
- Develop algorithms to solve molecular dynamics equations at high speed
- Nonlinear equations (develop algorithms to solve Navier–Stokes equations, etc. at high speed)
- Construct algorithms to optimize materials and device structures resistant to extreme environments based on environmental functions
- Construct optimization algorithms (regarding air, water, energy, agriculture, etc.) based on environment and infrastructure models (stories (5) and (6))

Initiate work on constructing habitable environments in extreme environments

- Develop AI robots, etc. resistant to extreme environments and capable of remote unmanned work
- Establish an approach to reducing material-transport costs (e.g. space elevators, space 3D printers)

Roadmap

Extreme environment simulation

Process (2/2)

Construction of habitable environments in extreme environments

- Check risk of extreme-environment habitats

Advances in comfort and security sciences

- Establish/select comfort/security models
- Set up development environment using calculations
- Economic/social motivations that encourage extreme-environment habitats

Necessary steps

Items related to quantum computers

Necessary steps	2024	2025-2030	2030-2040	Beyond 2040
■ Establish high-accuracy technology for observing space debris				
■ Achieve precise and high-speed orbital analysis calculations				
■ Establish techniques that enable an integrated approach combining theoretical and causal models				
■ Establish space-debris orbit prediction model using quantum computation				
■ Develop an algorithm to evaluate risk of collisions				
■ Set standards for evaluating a sense of comfort and security				
■ Analyze feasible parameter elements and set up a model foundation.				
■ Collect data for evaluating emotions through experiments, wearing of sensors, etc.				
■ Expand base of linear regression analysis (develop techniques to expand the application range beyond existing algorithms)				
■ Develop a comfort/security model through quantum linear regression analysis				
■ Within that model, identify computational tasks difficult to solve by a classical approach				
■ Establish a solution combining quantum computing and an algorithm that can predict human emotions				
■ Study ownership rights, etc. of land and resources in space from a space ethics perspective				
■ Design a migration incentive system				

More use cases are available on our website. We invite you to explore them.
https://www.quantum-computing-use-cases.nedo.go.jp/english/

More Use Cases

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This collection of use cases was obtained as a result of the work commissioned by the New Energy and Industrial Technology Development Organization (NEDO) "Cyber-Physical Development Business of Quantum/Classical Hybrid Technology/Study of Use Case of Quantum Technology" and the “Post-5G Information and Communications System Infrastructure Reinforcement R & D Project (Quantum Industrialization)/Comprehensive Study for Promoting the Industrialization of Quantum Computers ”.