Research Center Project

* Compile in English within 25 A4 pages.

Center name:

International Center for Quantum-field Measurement Systems for Studies of the Universe and Particles (QUP)

Host institution: High Energy Accelerator Research Organization (KEK)

Head of host institution: Masanori Yamauchi, Director General

Prospective Center director:

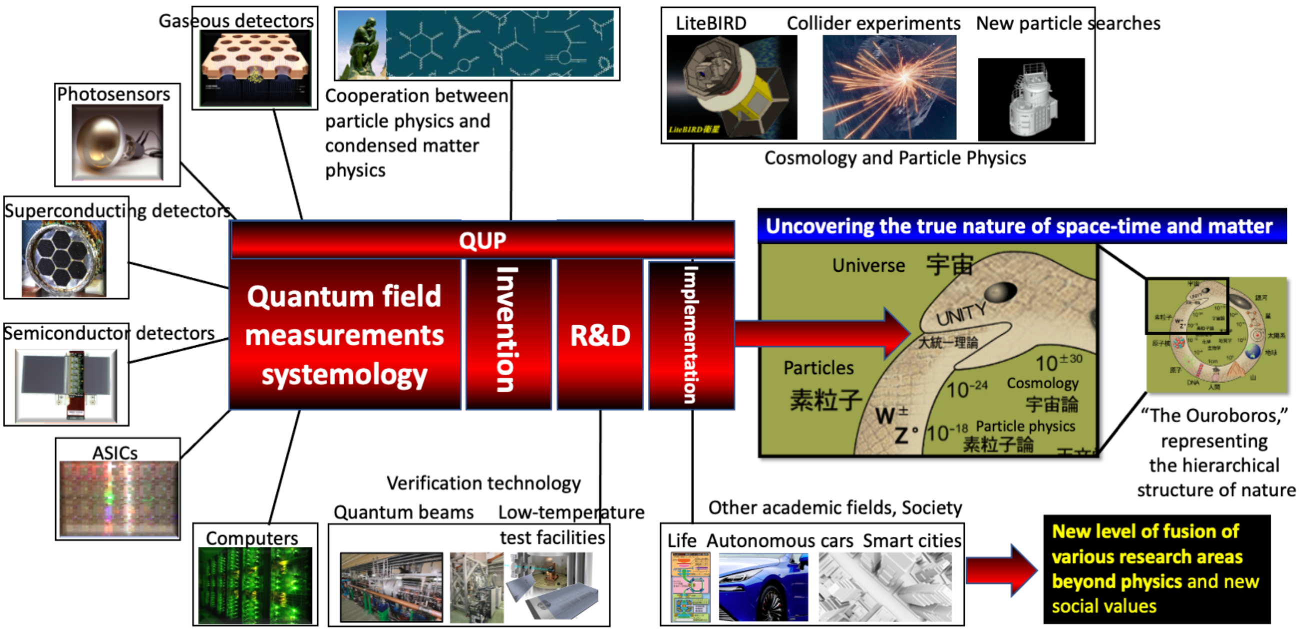
Masashi Hazumi, Professor, Institute of Particle and Nuclear Studies (IPNS), KEK

Prospective Administrative director:

Katsuo Tokushuku, Professor, Institute of Particle and Nuclear Studies (IPNS), KEK

1) Overall Framework of the Center Project

* Cleary and concisely describe your center's mission statement as a WPI center, its identity, and its goals toward achieving the objectives of the WPI program.



First of all, the basic idea (slogan for the public) of this center is **to bring new "eyes" to humanity and to look at the origin of this beautiful world (the true nature of time, space, and matter).**

<u>The missions of this center</u> are as follows.

- **Integrate** particle physics, astrophysics, condensed matter physics, measurement science, and systems science.
- **Invent and develop** new systems for measuring quantum fields (space-time with particles and quasiparticles created and annihilated, and associated physical quantities).

- Bring **innovation** to measurements in cosmological observations and particle experiments, and **elucidate** the true nature of space-time and matter.
- **Establish** a new measurement science, quantum field measurement systemology, as a science of means through the above practices.
- Last but not least, we will **create a new level of fusion of various research areas beyond physics** and new social values through application to other fields and social implementation.

The identities of this center are as follows.

I) The only center in the world that integrates the **invention** of new measurement principles for experimental cosmology and particle physics, the **development** of systems to realize these principles, and the **execution** of projects.

II) This center will conduct **interdisciplinary research on "means" or "methodologies."** It is at the meta-level, **leading to a new level of fusion of various research areas to produce academic and social values.**

III) Capability of characterizing measurement systems using the **various quantum beams** provided by KEK's accelerator facilities.

IV) Leveraging **our experience as a host of large-scale international collaborative experiments** in fundamental research fields to conduct international research collaborations at an unparalleled level.

V) Leveraging our **experience as an inter-university research institute**, we will lead the world and make significant contributions to the research and education of universities and research institutions in Japan and abroad.

Based on the above mission and identity, the goals of this center are defined as follows.

1) To invent new principles and measurement systems to search for theoretically predicted novel quantum fields.
2) To lead the world in the grand challenges of cosmology and particle physics by developing and implementing new quantum field measurement systems in international projects such as the LiteBIRD satellite project and collider experiments.
3) To propose and promote new projects based on new quantum field measurement systems.
4) To develop new methods of data analysis, which correspond to the "brain" of the measurement system, and apply them to cosmology and particle physics.
5) To establish a new measurement science, quantum field measurement systemology, as a "science of means" through the above practices.
6) To employ researchers whose primary goal is to give back to society, realize social implementation (smart cities, automatic driving, medical care, etc.), and at the same time, actively develop applications in other academic fields.
7) To cultivate the next generation of human resources who are proficient in systems science and have deep expertise.

2) World-Leading Scientific Excellence and Recognition

2) -1 Research fields

* Write in your target research field(s)
* Describe the importance of the target research field(s), including the domestic and international R&D trends in that research domain and neighboring field(s), and describe the scientific and/or social significance of the field(s).
* Describe the value of carrying out research in the field(s) as a WPI center (e.g., Japan's advantages in the subject fields, the project's international appeal as an initiative that challenges world-level science issues, and the future prospects of the research)
* List up to 5 centers either in Japan or overseas that are advancing research in fields similar to the center's field(s), and evaluate research levels between your center and those centers.
* Appendix 4: "Up to 10 English-written papers (review papers are also acceptable) closely related to the center's project and their list" (to be attached)

2) -1 -1 The target research field

The main target research field is mathematical and physical sciences, in particular particle physics and cosmology. However, the new quantum field measurement systems invented and developed at this center will lead to a new level of fusion of various research areas beyond physics. Relevant research areas include chemistry, biology, medicine, archeology, and even neuro-aesthetics.

2) -1 -2 The importance of the target research field, and the value of carrying out research in the field(s) as a WPI center

For the past half-century, particle physics, a field that originated in quantum mechanics, has been conducting fundamental research on quantum fields, which can be described only by field quantization beyond particle quantization. It is no exaggeration to say that the core of experimental approaches to solving the great mysteries of the universe, subatomic particles, and life can be traced chiefly back to the measurement of quantum fields. For example, at the B-factory experiment at KEK, the phenomenon of the bottom quark decaying into several other particles, such as charm quarks and electrons, was closely examined. Precise agreements with quantum field theory were found, which led to the Nobel Prize to Professors Kobayashi and Maskawa. The results of particle physics research based on quantum fields have resulted in many Nobel Prizes in Physics. The measurement technology cultivated there is a crucial technology for clarifying everything from the head to the tail of the Ouroboros serpent [see the figure in section 1) The overall picture of base formation], which represents the entirety of the natural world, from the universe to elementary particles, which are the root of the matter. For example, theoretical proposals that attempt to approach the grand challenges of science, such as the origin of our universe and the fundamental picture of the matter, consistently predict the existence of unknown elementary particles.

Thus, KEK is a world-class center for accelerator science. In connection with this, it occupies a globally dominant position as a place for the rapid development of measurement technology. However, the actual state of KEK's measurement technology is the fruit of individual researchers' heroic and artisanal efforts and cannot be said to be systematized. In this sense, KEK is not yet a center for measurement science. That is an obstacle that prevents further progress. To sublimate these explorations into a new phase, we are at a loss with the measurement technologies we have at hand, and we are in dire need of ideas for new measurement systems. Just as human activities realize through the excellent coordination of organs such as the eyes, hands, and brain, the quantum field measurement system consists of sensors corresponding to the eyes, operating mechanisms corresponding to the hands, and computers corresponding to the brain. Suppose individual development research is integrated and reexamined from first principles under the most advanced systemology (systems science). In that case, it will be possible to invent entirely new devices and discover completely new physics. It will be an attempt to reconstruct experimental science from the perspective of "measurements." That will enable us to identify overlooked measurement possibilities and optimal solutions for measurement methods. As an example of interdisciplinary research of particle physics and condensed matter physics, we may discover that we can perform a better measurement using phonons for an object previously measured using electrons.

Thus, to achieve the goal of revolutionizing the exploration of the universe and elementary particles, **this proposal creates a new field of quantum field measurement systemology as a "science of means."** It will give rise to the next generation of basic quantum technology, which will be the foundation for solving mysteries in many fields, including the universe, subatomic particles, condensed matter, and life. Furthermore, in innovation, where people often lose their ways, it will serve as a reliable lighthouse to illuminate the way ahead and naturally lead to broader applications and returns to society beyond the application to basic science.

2) -1 -3 Comparison with other centers around the world

In KEK, there are about ten faculty members and ten technical staff members in the support group for collaborative research related to measuring instruments and low temperatures. Still, as mentioned above, KEK has not become a world center for measurement science. On the other hand, some of the world's leading accelerator centers for particle and nuclear research are also centers for measurement science. CERN's Middle Term Plan calls for large-scale development under the title of "R&D for future detectors" at the cost of 42.7 FTEs, or 48 MCHF (about $60 million US) over five years (including labor costs). It has established itself as a hub for universities and research institutes in Europe and beyond. DESY in Germany, FNAL, and BNL in the U.S. are conducting extensive research in collider physics, astrophysics, and science using synchrotron radiation, similar to KEK. Each institution is actively developing its measuring instruments. Their future plans also indicate the importance of this development. They have established a test beam facility to provide beams to users worldwide, which is similar to what we are aiming for with this proposal. However, there is no example of an organization that integrates quantum field measurement and systems based on systemology, as in this proposal. With this proposal, we aim to create a major center that rivals these laboratories in terms of scale and will produce unique research. This scale will also allow for closer collaboration with other centers.

2) -2 Research objectives and plans

* Describe in a clear and easy-to-understand manner by the general public the research objectives that your project seeks to achieve by the end of its grant period (in 10 years). In that process, what world-level scientific and/or technological issues are you seeking to solve? What will be the expected impact of the scientific advances you aim to achieve on society in the future?

* Describe concretely your research plan to achieve these objectives and any past achievements related to your application.

The Standard Model of particle physics cannot solve four significant mysteries: The accelerated expansion in the very early universe named inflation; The dark matter; The dark energy; The fact that the universe has no antiparticles and appears to consist of only particles. To solve these mysteries, theorists have predicted the existence of novel quantum fields such as inflaton, axion, and supersymmetric particles. **If we discover even one such novel quantum field, it will lead to the Nobel Prize in Physics.** This is a driving force of the center and the above research goals are set to this end. We perform the invention, development, and implementation of innovative quantum field measurement systems to achieve the above goals. Major examples include a new measurement system using quasiparticles, a new semiconductor detector with more than two orders of magnitude better radiation tolerance than the previous one, integration of new sensor development and integrated circuit development, automation of analog integrated circuit development, and a superconducting detector array for the LiteBIRD satellite. The PIs in charge of each research will prepare and proceed with clear goals and project plans for the next 5 and 10 years. It is in general hard to set an accurate and quantitative goals in 10 years from now. Considering the fact that a new invention from the center could be a game changer, it is nearly impossible to do it in our case. However, for example, the LiteBIRD satellite will likely to be launched before the end of the WPI grant period, and could make a big discovery. Also, 10 years is a reasonable amount of time from designing a new experiment to produce new results, which will give us more chances of big discoveries.

Of the seven goals mentioned in (1), six of them, except for human resource development, are described in more detail in the following (human resource development is described in 4-2).

2) -2 -1 Invention of new principles and measurement systems to search for theoretically predicted novel quantum fields

<u>Invention of new measurement methods based on quantum field theory and advanced particle physics</u>

The identity of dark matter, one of the greatest mysteries in physics, has not even been discovered yet, and innovative ideas that do not adhere to conventional search methods are needed. The situation is similar for novel quantum fields such as inflaton, axion, and supersymmetric particles. To overcome the current problem, we need to interact and integrate with other research areas actively. Until now, the linkage between condensed matter physics and particle physics has been overlooked. However, there are various quantum fields of quasiparticles in various physical systems, and these fields should coexist with the quantum fields of elementary particles in matter. The active use of quantum field properties in condensed matter systems, such as phonons, magnons, and axions in solids, can open up new horizons in the search for new particles. It is also possible to propose an ideal material design from the viewpoint of particle physics, use it as a completely new detector, or apply theoretical methods for elementary particles to understand condensed matter systems. This center will promote collaboration between condensed matter physicists and particle physicists and contribute to creating a new academic field. We will carry out this research in the spirit of exploring all cases without exception, using the systems science methods of experimentalists.

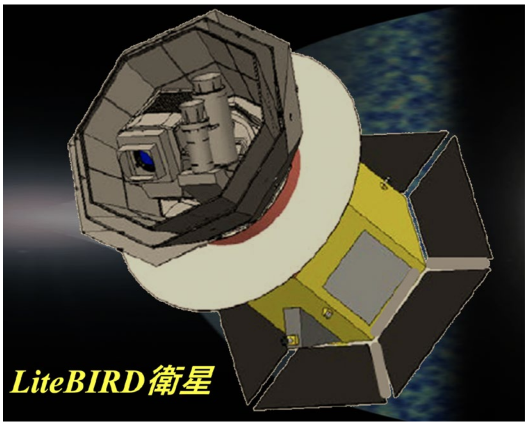
Development of new sensors and integrated circuits

Semiconductor detectors are one of the core measurement devices in particle physics. In this center, we will develop a new type of semiconductor detector with a radiation tolerance improved by more than two orders of magnitude compared to conventional sensors. It will enable particle physics experiments in harsher radiation environments. It will also lead to applications such as beam diagnostics for accelerators, which could not be carried out due to too high radiation levels, and the development of cameras that can withstand use in nuclear reactors. We have two directions in developing rad-hard technology for semiconductor devices. The first direction is to introduce new semiconductors such as CIGS to replace silicon. The CIGS sensors have been developed initially for solar cell applications. The SIGS can recover from radiation damage with compensation of the defects created by ions. It will be the first attempt to make a particle detector with CIGS focusing on the recovery features. We also plan to research the wide-gap semiconductor materials, such as diamond, GaN, AlN, to obtain a comprehensive understanding of the mechanism of radiation damage.
The second direction is the development of the rad-hard readout chip. The RD53 Collaboration was established in 2013 to develop the next generation of pixel readout chips for the High Luminosity LHC detector upgrades. This work is nearing completion now. However, a new mandate is being articulated, which is to embark on a new technology development cycle leading to a further generation of pixel readout chips in a more advanced CMOS technology node of 28nm. CERN is pursuing this node as the next IC technology for leading-edge particle physics projects. We propose for this center to join RD53 as a new member institute. PI Garcia-Sciveres is the current co-spokesperson and co-founder of RD53, and PI Bortoletto is the lead of the most recent member institute of RD53 (Oxford). WPI will be the first Japanese member institute of RD53. This new generation chip can also be used for the newly developing semiconductor sensor.

In cosmological observations, **superconducting detectors** have become a central measurement device due to the stringent observation performance requirements. This center will develop a new superconducting transition-edge sensor array with a unique design and cryogenic readout circuit to suppress the high level of cosmic ray-derived noise for use in space. Three PIs, Adrian Lee, Masashi Hazumi, and Masaya Hasegawa, will develop and evaluate the TES focal plane system for the LiteBIRD satellite project. One of the main obstacles at LiteBIRD is primary cosmic rays, which inject noise into the system. To mitigate the effect, we need to invent a unique design in which phonons, the quantum field of thermal vibrations created on the silicon substrate by cosmic rays, are efficiently blocked from the TES bolometers. Our team is leading the world in this particular application. Since this R&D is essentially "phonon engineering," it has a wide range of potential applications to other fields. We will also develop a new type of superconducting detector for X-ray observation and dark matter search. In addition to the above, we will invent new kinds of gaseous detectors with new readout, optical sensors, and scintillators with the cooperation of domestic and foreign researchers. One of the unrivaled features of this center is that it has access to a wide range of beam test facilities using KEK's various quantum beams. It will dramatically increase the efficiency and speed of the detector development described above.

Improving the performance of sensors requires improving the performance of **integrated circuits** that process vast amounts of signals. We will invent a world-leading measurement system by integrating the development of new sensors and integrated circuits through a systems science approach. The RD53 mentioned above is an example. Another example, based on the concept of systemology, is the development of novel methods to create analog circuit designs and layouts for ASICs automatically based on requirements from experimenters. The bottleneck of ASIC development at the moment is the person-power of skilled ASIC designers. The automatic designer tool we develop will solve the problem and boost the design capabilities.

2) -2 -2 Development and implementation of a new quantum field measurement system in international projects such as the LiteBIRD satellite project and collider experiments, leading the world in the grand challenge of space and particle research.



We will develop a superconducting transition-edge sensor array system for the LiteBIRD satellite proposed by the director of this center and selected as JAXA's strategic L-class mission #2. LiteBIRD is a mission to explore the universe before the hot Big Bang. Because of its scientific excellence, it has been selected as a priority large research project in the Master Plan 2020 of the Science Council of Japan. It is also a project listed on the Roadmap 2020 of the Ministry of Education, Culture, Sports, Science, and Technology (MEXT.) In particular, LiteBIRD can test the inflation hypothesis, which states that a new quantum field called an inflaton caused the accelerated expansion of the universe. It is a project that tackles head-on the grand challenges concerning the universe, space-time, and elementary particles. This center will promote LiteBIRD as the flagship project. In addition, we will implement new quantum field measurement systems in international projects, including those at particle colliders.

2) -2 -3 Proposal and promotion of a new project based on a new quantum field measurement system

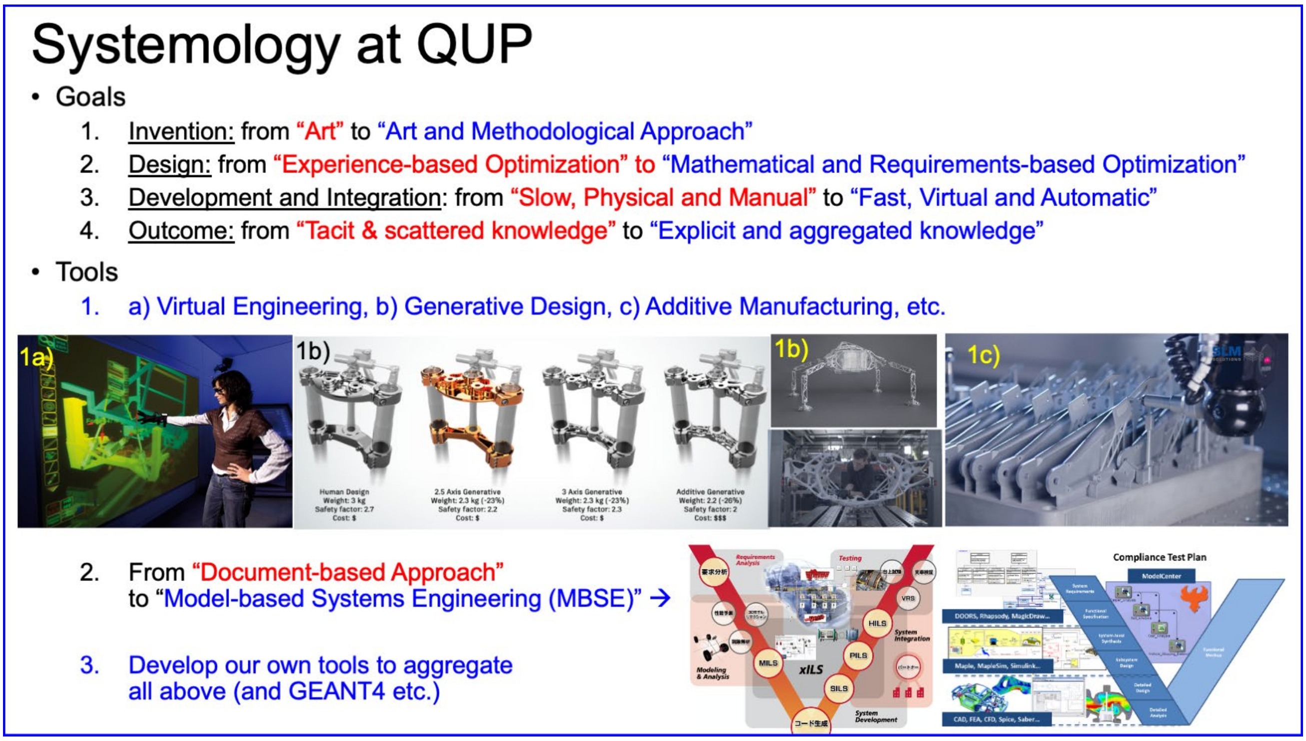
Based on the invention described in 2-2-1, we will launch an international project to search for a new quantum field. Since we do not know the optimal solution, systematic research starting from idea generation is necessary. Candidates include the axion search using magnons and the dark matter search using phonons. We will use the full power of this center to compare the merits and demerits of various ideas using a systems science approach. We will select projects with the best chance of success. We will promote this activity by a "good mix" of bottom-up, free-thinking by scientists, and top-down, system science.

2) -2 -4 Development of a new method of data analysis corresponding to the "brain" of the measurement system, and its application to cosmology and particle physics

Just as human activities realize through the coordination of organs such as the eyes, hands, and brain, the quantum field measurement system consists of sensors corresponding to the eyes, various operating mechanisms corresponding to the hands, and computers and software corresponding to the brain. The center will promote the analysis of data corresponding to the "brain" in the search for new quantum fields by making full use of a variety of data from cosmological observations to particle physics experiments. We will introduce new computational and informational methods that go beyond known methods in both new and existing experiments. We will implement them using the resources of the KEK Computational Research Center.

2) -2 -5 Establishing a new measurement science, quantum field measurement systemology, as a science of means through the above practices

We will actively implement systems modeling languages and practice systems engineering methods in all our projects. The lessons learned will be fed back, and systemology (systems science) will be developed. The engineers of the Systemology Support Section will support this process and will also promote basic systemology research. The following figure shows the basic concept of systemology pursued at this center.



2) -2 -6 Employ researchers whose primary goal is to give back to society realize social implementation (smart cities, automated driving, medical care, etc.). At the same time, we will actively develop applications in other academic fields.

We pursue the application of semiconductor detectors to social infrastructure (smart cities), automobiles, and medicine. We will also develop academic applications of semiconductor detectors and superconducting detectors in fields other than cosmology and particle physics. Specific examples include: high-precision position detectors for structural biology; muon image detectors for muon microscopy; high-sensitivity magnetic field measurement for brain measurement. We will also actively explore completely new developments in an invention-oriented way.

Our challenges include the realization of a non-contact shaft-bearing system, which will bring a drastic change in designs of various important building blocks having rotational structures, such as motors. There are two key technologies, i.e., (i) control of Casimir force and thermal emission, and (ii) quantum sensing having extremely high sensitivity. Casimir force arises from quantum and thermal fluctuations, and has been measured in a typical system consisting of two bodies with the gap distance less than a few microns. While all of previous measurements on Casimir forces have been conducted in equilibrium, Casimir force in non-equilibrium, where the bodies and the environment have different temperatures, is expected to significantly extend the degree of the control range since thermal emission occurs as an additional channel. We recently developed a theoretical framework for the control of non-equilibrium Casimir force, where thermal emission occurs, in a two-body system as shown in the figure below.

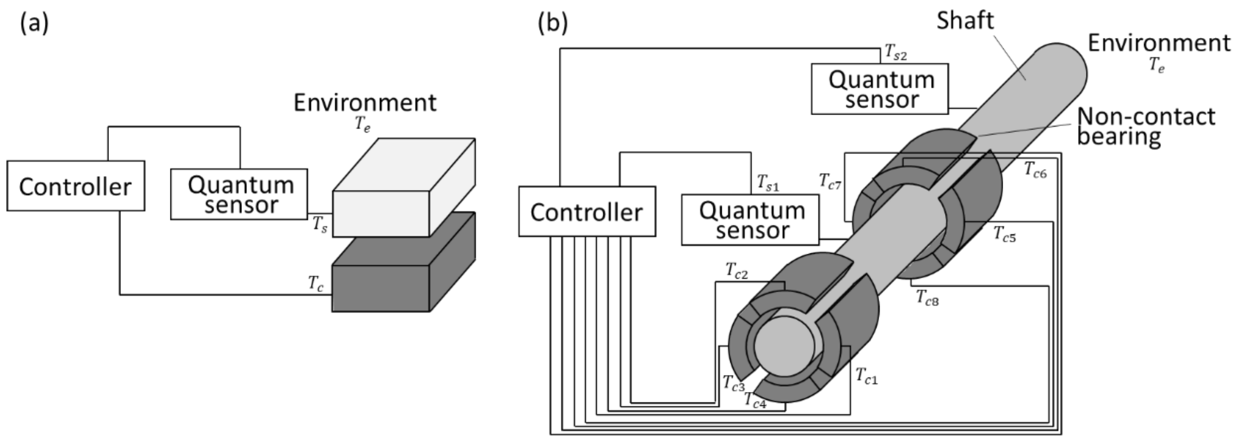


Fig.(a) Control of non-equilibrium Casimir force in a two-body system, where thermal emission occurs. (b) Non-contact shaft-bearing system enabled by manipulating Casimir force and thermal emission.

The top plate can stay at a distance away from the bottom plate indefinitely, by detecting the temperature of the top plate and adjusting the temperature of the bottom plate, through the use of a control theory. In the system, the sensor needs high accuracy with a few tens mK for the temperature measurement, which is achievable by a quantum sensor. While a class of nitrogen-vacancy center in diamond has been mainly investigated for quantum sensors, we will develop silicon carbide based quantum sensors since silicon carbide technology has been well established in Toyota group companies, e.g., silicon carbide-based power devices have been installed in Toyota vehicles. In five years, we will measure non-equilibrium Casimir force in a typical two-body system for the first time in the world. In ten years, we will experimentally demonstrate a non-contact shaft-bearing system (Fig. 1b). Quantum sensors detect temperatures Ts1,2 in a few spots on the shaft, and the controller may determine the temperature Tc1-8 of each piece of the bearings. Simultaneously, we will find possible application scenarios in the space industry, the mobility industry, and future cities such as Toyota Woven City, and show a few experimental demonstrations.

2) -3 System for advancing the research

* Describe the center's research organization (including its research, support and administrative components) and your concept for building and staffing the organization. Regarding the composition of the center's personnel, describe measures to obtain diversity such as gender balance.
* Describe your concrete plan for achieving the center's final staffing goal, including steps and timetables.
* If the center will form linkage with other institutions, domestic and/or foreign, *by establishing satellite functions*, provide the name(s) of the partner institution(s), and describe their roles, personnel composition and structure, and the collaborative framework with the center project (e.g., contracts to be concluded, schemes for resource transfer).
* If the center will form linkage with other institutions, domestic and/or foreign, *without establishing satellite functions*, provide the names of the partner institutions and describe their roles and linkages within the center project.
* Appendix 5: "List of Principal Investigators" (If there are changes from the PI list in the first screening application documents, describe the points changed and reasons.) (to be attached)
* Appendix 6: "Biographical sketch of principal investigator" (to be attached)
* Appendix 7: "Composition of personnel in center" (to be attached)
* Appendix 8: "Letters from researchers invited from abroad or other Japanese institutions expressing their intent to participate in the center project" (to be attached)

Prof. Hazumi, the prospective director of the center, has a world class record in both particle physics and experimental cosmology. He has more than 40,000 citations and has given 22 invited talks at international conferences in the last 5 years. He is also a member of the selection committee for the International Conference on Superconducting Detectors of the International Society for Optical Engineering (SPIE). He is also taking a leadership role as the world PI of the LiteBIRD satellite project, which has about 300 researchers from 12 countries. It is no exaggeration to say that his time is 100% used for the Center. Even when he is not physically present at the Center in KEK, his effort will be engaged for activities as the world representative PI of LiteBIRD, the flagship project of the Center, activities at three satellites, and promotion activities of the Center at international conferences and other research institutes around the world. Regarding his FTE management, in view of his role as the face of the center, and as the LiteBIRD project progresses in the future, necessary corrections will be made promptly.

Prof. Hanagaki, the prospective deputy director of the center, has a deep knowledge of semiconductor detectors and is working on the world's largest international project (ATLAS experiment.) He has also led the construction of a new test beamline at KEK, and serves as the head of the KEK Instrument Development Office. He is appointed as Deputy Director of IPNS in April 2021. He will be the core of the close collaboration between this center and IPNS. **Prof. Tokushuku, the prospective administrative director**, has a wealth of experience as the former director of IPNS and personal connections cultivated through large-scale international projects (ZEUS, ATLAS). He makes full use of this experience to manage the administrative department of the center.

In selecting PIs, we chose researchers who are consistent with the center's mission, identity, and goals. Priority was given to the highest level of competence. Diversity was also taken into consideration, and the ratio of female PIs is approximately 40%. Prof. Lee of the University of California, Berkeley, is a pioneer of superconducting detectors for CMB observations. He has been collaborating with Prof. Hazumi for more than ten years. Prof. Bortoletto, famous for her development of semiconductor detectors, is Head of the Particle Physics Department at University of Oxford and Deputy Coordinator of the EU detector development project AIDA. She has more than 190,000 citations in academic papers and is the editor of the journal "Nuclear Instruments and Methods." Dr.

Garcia-Sciverse is a Senior Research Scientist at Lawrence Berkeley National Laboratory. He is world-renowned for his work in instrument technology for particle physics experiments. He has served as Deputy Director of the Berkeley Center for Particle Physics and Principal Investigator of CERN's RD53A instrument development project, where he led the development of ASICs for silicon detectors. The domestic PIs were selected based on a balance of world-class researchers and young researchers who are just emerging. Prof. Yamazaki is a member of the Science Council of Japan. Prof. Nakahama (Fumiko Yonezawa Prize, Toshiko Yuasa Prize) and Dr. Hasegawa (Breakthrough Prize in Fundamental Physics) are award-winning researchers. Prof. Miyahara is a distinguished researcher of the MEXT and an editorial board member of essential journals (editorial board member of the English journal of the Institute of Electronics, Information and Communication Engineers (IEICE), etc.). Moreover, one of the PIs, Dr. Iizuka of Toyota Central R&D Labs, is an enterprising researcher in engineering. He has made achievements in low-noise communication technology, wireless power transfer technology, etc., in the challenges of automated driving and smart cities, a collection of advanced technologies. We expect that his group will contribute to novel sensing technologies and their applications at this research center. The average age of the PIs is 47 years old, making them a strong group of researchers who are in the prime of their careers and can lead the world.

We have already started discussing with these PI candidates about the organization of the center. As for the support of external PIs, we can be flexible within the current KEK rules, from partial employment at this center on a cross-appointment basis to reward payments based on effort. Therefore, we can quickly start up research as soon as this proposal is approved. The recruitment of researchers and postdoctoral fellows will be phased in from the second half of the 1st fiscal year to the 2nd fiscal year so that the entire personnel will be in place by the end of the 2nd fiscal year.

The center will set up satellites at the Nanotech Lab of the University of California, Berkeley, and the JAXA Institute of Space and Astronautical Science to fabricate superconducting sensors. In addition, the center will place another satellite at the Toyota Central R&D Labs to vigorously promote efforts for social implementation. MOUs will be signed with these three research institutes as soon as possible after the formation of the center. We will secure rooms for the satellites, make arrangements for the use of resources (sensor fabrication equipment, etc.), and hire researchers and technical staff for the satellites.

Six of the PI candidates belong to KEK (Yu Nakahama joined KEK as an associate professor on August 1st). It is also planned to hire four senior researchers (100% effort) as soon as possible. It is envisioned that these senior researchers will become new PIs as needed. These senior researchers will be 100% KEK affiliated. In addition, 100% effort CO-PI may be allocated to each overseas PI, who will be stationed at the Center in KEK for smooth cooperation. The existing building will be repaired and used as the main research building and experimental building of the Center. This experimental building is an excellent large facility created for the TRISTAN collider experiment. Through the large-scale repairs, researchers at the Center such as PIs, senior researchers, post-docs, and graduate students will attain the concentration and engagement of research power under one roof of the "non-virtual research center."

a) Principal investigators (full professors, associate professors, or other researchers of comparable standing)

* Paste onto table a) in Appendix 7.

(persons)

	At beginning of project	At end of FY 2021	Final goal (Date: April, 2023)
Researchers from within the host institution	5	5	5
Foreign researchers invited from abroad	3	3	3
Researchers invited from other Japanese institutions	5	5	5
Total principal investigators	13	13	13

b) Total number of members

* Paste onto table b) in Appendix 7.

	At beginning of project		At end of FY2021		Final goal (Date: April, 2023)	
	Number of persons	%	Number of persons	%	Number of persons	%
Researchers	20		20		67	
Overseas researchers	3	15.0	3	15.0	21	31.3
Female researchers	6	30.0	6	30.0	15	22.4
Principal investigators	13		13		13	
Overseas PIs	3	23.1	3	23.1	3	23.1
Female PIs	5	38.5	5	38.5	5	38.5
Other researchers	7		7		54	
Overseas researchers	0	0.0	0	0.0	18	33.3
Female researchers	1	14.3	1	14.3	10	18.5
Research support staffs	3		3		20	
Administrative staffs	26		26		25	
Total number of people	49		49		112	

2) -4 Securing research funding

Past record

* Give the total amount of research funding (e.g., competitive funding) secured by the principal investigators who will join the center project. Itemize by fiscal year (FY2016-2020).

The following is a list of competitive research funds and other research expenses that PIs participating in the Center have received in the past. (For Japanese researchers, indirect costs are included.

	FY2016	FY2017	FY2018	FY2019	FY2020	Total	Annual Avg.
Japanese PIs	204,101	154,687	192,488	135,532	163,267	850,075	170,015
Overseas PIs	250,041	627,283	932,448	865,181	798,009	3,472,963	694,593
Total	454,142	781,970	1,124,937	1,000,713	961,276	4,323,038	864,608
							(K yen)

Over the past five years, domestic PIs alone have earned approximately 170 million yen/year (including indirect costs), and overseas PIs have earned approximately 690 million yen/year.

Funding prospects after the establishment of the center

* Based on the past record, describe your concrete prospects for securing resources that match or exceed the WPI grant (FY2021-2025).

* Calculate the total amount of research funding (e.g., competitive funding) based on the amount of funding that the researchers will allocate to the center project. Be sure that the funding prospects are realistically based on the past record.

The following describes our plan to secure funding. The total number of staff at the center (executive members, researchers, and technical and administrative staff for research support) is 112. The allocation plan for this staffing and project promotion is shown below.

(Thousand yen)

			Financial resources	1st year	2nd year	3rd year	4th year	5th year	6th year	7th year	8th year	9th year	10th year	
				2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	
Personnel Costs	Director		WPI grant	7,500	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	
	Deputy Director		Funding from host institution	7,000	7,000	7,000	7,000	7,000	7,000	7,000	7,000	7,000	7,000	
	Administrative Director		WPI grant	10,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	
	Principal investigator		WPI grant	18,000	36,000	36,000	36,000	36,000	36,000	36,000	36,000	36,000	36,000	
			Funding from host institution	13,300	26,600	26,600	26,600	26,600	26,600	26,600	26,600	26,600	26,600	
	Researcher	Senior Researcher	WPI grant	0	24,000	48,000	48,000	48,000	48,000	36,000	24,000	12,000	0	
			Funding from host institution	10,650	42,600	42,600	42,600	42,600	42,600	54,600	66,600	78,600	90,600	
		Postdoc	WPI grant	0	166,250	245,000	245,000	245,000	224,000	203,000	182,000	161,000	133,000	
			External Fund	7,000	35,000	35,000	35,000	35,000	56,000	77,000	98,000	119,000	140,000	
	Technical staff	Engineer	WPI grant	0	45,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	
		Technician	WPI grant	0	26,250	35,000	35,000	35,000	28,000	21,000	14,000	7,000	0	
			Funding from host institution	21,000	42,000	70,000	70,000	70,000	77,000	84,000	91,000	98,000	105,000	
	Administrative staff	Head, QUP office	WPI grant	5,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	
		QUP office full-time staff	WPI grant	10,500	21,000	21,000	21,000	21,000	21,000	21,000	21,000	21,000	21,000	
			Funding from host institution	4,900	8,400	3,500	0	0	0	0	0	0	0	
		QUP office part-time staff	WPI grant	24,000	63,600	63,600	63,600	63,600	63,600	63,600	63,600	63,600	63,600	
	University Research Administrator		WPI grant	0	56,000	56,000	56,000	56,000	56,000	56,000	56,000	56,000	56,000	
	Research Assistant		WPI grant	4,500	18,000	27,000	27,000	27,000	27,000	27,000	27,000	27,000	27,000	
Costs Activities Project	Startup costs		WPI grant	42,000	36,000	-	-	-	-	-	-	-	-	
	Travel Costs		WPI grant	9,000	36,000	36,000	36,000	36,000	36,000	36,000	36,000	36,000	36,000	
	Costs of Equipment		WPI grant	76,300	223,500	123,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	
	Costs used at satellites		WPI grant	25,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	
	Costs of international conference		WPI grant	5,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	
	Rental fees for research space		Funding from host institution	23,300	46,600	46,600	46,600	46,600	46,600	46,600	46,600	46,600	46,600	
	Facility usage fee		Funding from host institution	0	122,930	122,930	122,930	122,930	122,930	122,930	122,930	122,930	122,930	
	research expenses		External Fund	100,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	
	Public relations expenses		WPI grant	4,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	
Center director's discretionary expenses			Funding from host institution	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	
Financial resources			WPI grant	240,800	856,600	855,600	735,600	735,600	707,600	667,600	627,600	587,600	540,600	
			Funding from host institution	130,150	346,130	369,230	365,730	365,730	372,730	391,730	410,730	429,730	448,730	
			External Fund	107,000	335,000	335,000	335,000	335,000	356,000	377,000	398,000	419,000	440,000	
			Total	477,950	1,537,730	1,559,830	1,436,330	1,436,330	1,436,330	1,436,330	1,436,330	1,436,330	1,429,330	13,622,820

- **From the WPI program: 6,555.2 million yen**

  ① Personnel cost (corresponding to FTE for the center)
  - For the director, administrative director, PIs, Co-PIs (tenured researchers outside KEK), postdocs
  - Personnel expenses for three postdocs hired in Japan (but outside KEK) will be transferred to the appropriation from the host institution (i.e., external funds) every fiscal year after JFY R8 (6th year).
  - Engineers and technicians to be recruited from domestic and overseas institutions.
  - Full-time staff at the QUP office and URAs of the QUP Strategy Office
  - Research Assistants (graduate students)

  ② Project promotion cost
  - Start-up cost (excluding tenured researchers at KEK, 1,000 kyen/person, only for the 1st year)
  - Expenses for international conferences
  - Expenses for travels
  - Expenses for equipment (infrastructure development for research, lease payments for copy machines, etc.)
  - Expenses for operating satellites (Berkeley, JAXA, Toyota)
  - Expenses for outreach
- **Sum of the appropriation from the host institution and external funds (KAKENHI etc.): 7,067.62 million yen**

  ① Personnel cost (corresponding to FTE for the center)
  - For the deputy director, PIs and Co-PIs who are tenured at KEK
  - KEK's technicians
  - Members of KEK Administration Bureau who support the center
  - Under the leadership of Director General, KEK plans to sequentially allocate tenure positions in a timely manner for senior researchers and engineers and share labor costs.

  ② Project promotion cost
  - Amount equal to the space charge for residential and laboratory buildings
  - Amount equal to fees for the use of facilities
  - Research funds (expecting 300 million yen/year)
    As mentioned above, the domestic PIs of the center alone have received an average of approximately 170 million yen annually. Overseas PIs have received more. If we scale the amount with expected FTEs, we expect 140 million yen/year approximately. Thus 310 million yen/year is expected from PIs alone. Since we also expect contributions from the LiteBIRD-related budget and external funds obtained by other domestic researchers (senior members and postdocs), we are confident that we will achieve 300 million yen/year.

  ③ Director's discretionary budget (50 million yen/year)
- **Responding to the gradual decline in subsidies after the sixth year**

After the sixth year, we will constantly review the priority areas of the Center's activities according to the scale of the gradual decrease in subsidies. We will further revitalize the Center's activities by employing postdoctoral researchers in areas where we can actively obtain external funding.

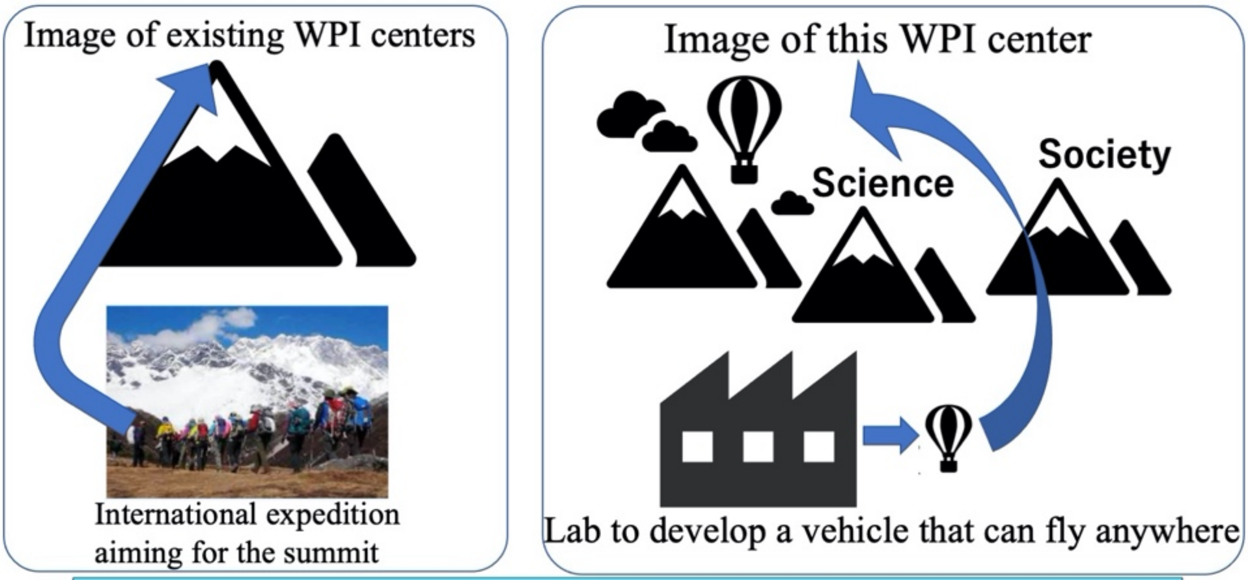
2) -5 Interdisciplinary research

* Describe the fused research domains, why interdisciplinary research is necessary and important in the target field(s), and what new field(s) can be expected to be created by way of this project. Describe your concrete strategy for fusing different research domains and creating new field(s) by the fusion.

In this center, researchers in particle physics, astrophysics, condensed matter physics, quantum beam science, measurement science, and systems science will come together to KEK, where outstanding research is advanced, and conduct interdisciplinary research and bring about innovations in quantum field measurement systems. One of our main goals is to solve the great mysteries of the universe, space-time, and elementary particles. Since there is no example in the world where interdisciplinary research on such a scale is carried out in an integrated manner, from invention to development to project implementation, the Center will become a world-leading center and further accelerate the interdisciplinary research. In our interdisciplinary research, mathematical and information science will play an essential role as the foundation and common language to support all activities.

Through interdisciplinary research at this center, KEK will be able to open up new research areas for KEK, which goes beyond its previous duties. For example, since this center will provide KEK with a solid foundation for research activities in astroparticle physics, it is expected that the scale of efforts so far will be greatly expanded. There are many research groups around KEK who are interested in various QUP activities. Collaboration with such groups is also beneficial, and the results of QUP can greatly support KEK's research as a whole. The research of this center, which creates a new eye called the quantum field measurement system, will be incorporated into the host organization, KEK, in this way as well.

This center will conduct interdisciplinary research on "means" or "methodologies." It is at the meta-level, leading to a new level of fusion of various research areas to produce not only academic but also social values. The new "eyes" will lead to applications in other fields, new social implementation, and social contribution. The figure below shows our basic idea. The existing WPI centers promote a fusion of researchers from various research areas who share the "goal" of solving academic mysteries. The research style of this center differs in that it brings together researchers from different fields in search of "new means." That will lead to breakthroughs in the studies of the universe, space-time, and elementary particles, but the "new means" will also generate application fields and social contributions beyond these goals.



Meta-level interdisciplinary fusion for means, not for a single goal, to produce academic and social values

The "extraordinary requirements" of particle and space projects lead to unique and disruptive innovations because they are not born from the needs of society. As for the concept of the future society, such as smart cities, smart factories, and automated driving, AI will utilize information collected from everywhere, social infrastructure, vehicle systems, and the people who use them. To innovate toward such a new society, ultra-sensitive sensor systems embedded in all kinds of things, which can measure at the quantum level, will be indispensable as the foundation of social infrastructure. If we take the relationship between space observation and automated driving/smart cities as an example, we see exciting similarities in the means. In automated driving, the frequency of millimeter-wave radar (79 GHz) needs to be further increased. On the other hand, LiteBIRD observes in higher frequency bands (up to 448 GHz), which opens up a possibility of technology transfer from space observation to automatic driving. On the other hand, LiteBIRD needs to suppress the interference of radio waves communicating with the ground to the superconducting sensor for observation. It is essentially the same problem as the interference of many radio-wave sources in the smart city concept. Thus, it creates a research topic of transfer from social implementation technology to space observation. In this way, the fusion of different fields can produce entirely new developments.

In addition to activating the global collaboration of manufacturing laboratories by the three satellites (Berkeley, Institute of Space and Astronautical Sciences at JAXA, and Toyota Central R&D Labs), we will try to create partnerships with other WPI centers. One example is the collaboration with the Kavli Institute for the Physics and Mathematics of the Universe (Kavli IPMU) at the University of Tokyo, which studies the universe with mathematics and theoretical physics. Our attempt will be an evolution of the WPI centers as a group. Our center, which will lead the world in experimental science, and the Kavli IPMU, which leads the world in theory and mathematics, will be the two wheels of experiment and theory. We will also contribute to other WPI centers by providing the means of measurement systems, which will significantly contribute to the global presence of the WPI alliance.

3) Global Research Environment and System Reform

3) -1 System for advancing international research

* Describe your concrete plan for building an international research center including the makeup of its foreign researchers, establishment of oversea satellites, or similar functions. Include a time schedule for the plan.

* Describe concretely your strategy for staffing foreign researchers (e.g., postdoc positions) through open international solicitations. Describe the procedures you will use to do so.

* Describe measures to help foreign researchers sustain and strengthen their activities under conditions when international exchange is limited.

The number of foreign PIs in the center is 3 out of 13 (23%), which meets the criteria. In addition, PIs of Japanese nationality are also actively engaged in international collaborative research. Therefore, with these core members, we can form an international center without problems. The center plans to set up a satellite in Berkeley in the first year.

Recruitment of KEK researchers is already underway internationally. From the beginning, this center will also conduct an internationally open recruitment process and actively recruit excellent foreign researchers. The PIs of this center are all active internationally. Taking the LiteBIRD satellite project promoted by the Director as an example, about 70% of the 300 members belong to foreign countries. We expect that many excellent researchers will come from abroad to make full use of these connections. It will naturally lead to a structure in which more than 30% of the researchers at this center are foreign nationals.

The center director and each PI will discuss the recruitment timing of the researchers. There is a possibility that we need to delay the recruitment due to the impact of COVID-19. On the other hand, it is essential to employ excellent researchers promptly in the worldwide competition. Therefore, we may hire researchers without coming to the center when hiring if they can start working remotely. This arrangement is possible since there is already such a case at KEK.

3) -2 Establishment of international research environment

* Describe your concrete strategy for establishing an international research environment, administration system, and support system (e.g., appointment of staff and provision of startup funding) to accommodate researchers from overseas.

* Concretely describe how the center will provide an environment in which researchers can work comfortably on their research by being exempted from duties other than research and related educational activities, and how they will be provided adequate staff support to handle paperwork and other administrative functions. Include your procedure and time schedule.

* Describe your strategy, procedure and timing for periodically holding international research conferences or symposiums (as a rule, at least once a year).

The center will perform its duties in English and will hire and assign administrative staff who can handle this. In the first and second years of this center, start-up research funds will be provided to PIs to concentrate on their research. Administrative staff and URA in the QUP Office will take charge of Logistical tasks so that PIs can concentrate on their research. In principle, KEK duties other than research and education are not assigned to WPI researchers. In the first and second fiscal years of the center's accounting, the center will provide PIs start-up research funds to start their research as early as possible.

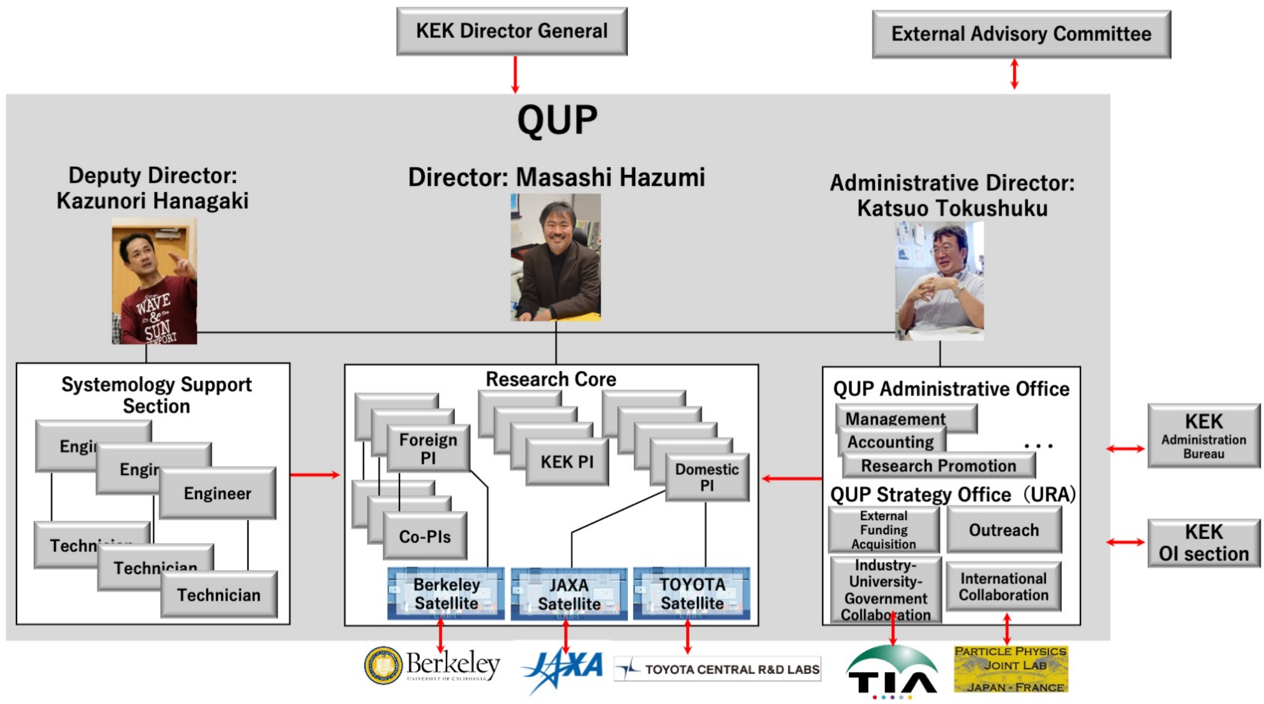
KEK hosts large-scale international collaborations such as Belle II and T2K and accepts many collaborators from Japan and abroad. Of the more than 8,000 visitors each year, about 2,000 are overseas.

Therefore, we have one of the best foundations for an English environment in Japan. Compared to overseas research institutions, however, there are still areas for improvement. The QUP office will expand its support for overseas researchers. In addition, we will aim for synergistic enhancements by working closely with the International Office and the Joint Usage Support Office of KEK, which is in charge of user support, to provide support and convenience to researchers in their research and daily lives.

The center will hold international research conferences on a regular basis. Since it is difficult to organize a face-to-face conference in the fiscal year 2021 under the COVID-19 situation, we will hold a Kick-off symposium online to hear PIs' plans, discuss joint research among PIs and hot and emerging ideas in the fields. After that, we will hold the symposium every year, synchronizing with the external advisory committee meeting for the annual evaluation. Each time, we will set a theme that focuses intensely on several PIs research topics. We plan a combination of that theme and an overview of the research field.

3) -3 Center management and system reform

* Describe the role of the center director and the administrative director.
* Concretely describe your concept for establishing an administrative organization, the center’s decision-making system and how authority is allocated between the center director and the host institution. (Describe concretely the mechanism for decision making when the person in charge of management and the person in charge of research and education are different, and describe the responsibility relationship between the two.)
* Concretely describe how the center will adopt a rigorous system for evaluating research and will introduce a system for merit-based compensation (e.g., annual salary scheme). Describe your procedures and timing for operationalizing these systems.



3) -3 -1. Decision-making mechanism

The organizational chart of this Center is shown above. **The KEK Director General** is responsible for creating the necessary environment for the Director of the Center to demonstrate leadership and coordinate the involvement of KEK researchers and administrative staff in the Center. **The**

Director of the Center makes the final decisions on important matters such as personnel, budget, and research goals and policies. **The Deputy Director** is in charge of the systemology support section and is responsible for ensuring that systemology methods are implemented and take root in all projects under the goals and policies set by the Director. In addition, through the practice of this research, the deputy director and the Director of the Center will create a new academic field called quantum field measurement systemology. **The Administrative Director** has the responsibility and authority to expand strategic collaborations, plan and execute strategies for obtaining external funding, and conduct administrative tasks to realize the goals set by the Center Director. Each PI is responsible for determining the approach of his or her research group and for autonomous management, including the acquisition of external funding.

The operation of the center will be carried out with top-down approach by the Center Director's decision. Under the leadership of the Center Director, a "Center Steering Committee Meeting" will be held as needed (once a month, but more frequently if necessary). The meeting members include the Center Director, the Deputy Director, the Administrative Director, the PI representative, and the Systemology Support Section representative, to discuss critical operational matters such as personnel, budget, and research goals and policies. In this way, the deputy director, the administrative director, the research core, and the systemology support section will understand the director's goals and policies and work together as a whole. A "PI meeting" will be held periodically, in which members of the Center Steering Committee, all PIs, and Co-PIs(*) can participate to discuss resources needed for research, etc. At PI meetings, PIs (or Co-PIs) will take turns to report on their research progress and discuss specific research collaborations among PIs. An "external advisory board" consisting of five prominent researchers from Japan and abroad will be established to evaluate the center's operation from a higher perspective and provide beneficial advice.
(*) The Co-PI system enables overseas PIs to work at the center even when it is difficult for them to travel abroad due to the corona pandemic; in case needed, overseas PIs may hire young researchers at the associate professor level as Co-PIs, and the Co-PIs will be stationed at the center to maintain a close relationship between the center and the overseas PIs.

3) -3 -2. Support divisions

We will establish (1) the Systemology Support Section, (2) the QUP Strategy Office, and (3) the QUP Office within the Center as research support organizations. (1) will be managed by the Deputy Director, and (2) and (3) by the Administrative Director.

The Systemology Support Section

This section provides systems engineering support and systems science support to PIs using systems modeling languages (such as SysML). Furthermore, through the lessons learned, this section will create a new discipline of quantum field measurement systemology under the supervision of the Director and Deputy Director.

The QUP Strategy Office

It is a URA organization responsible for strategically essential matters in the center's operation, such as acquiring external funds, industry-academia-government collaboration, international collaboration, and outreach. We consider industry-academia-government cooperation and international cooperation to be essential. We plan to connect with the Tsukuba Innovation Arena (TIA) established to accelerate the innovation in Japan for the former purpose. An example of international collaboration is the Toshiko Yuasa Laboratory (TYL), which Japan and France are promoting. The virtual laboratory was established in 2006 by KEK, CNRS/IN2P3, and CEA/Irfu, named after Dr. Toshiko Yuasa, a female physicist who went to France during and after World War II and made significant achievements in particle and nuclear physics. At TYL, we have collaborated in a wide range of fields, from detector technology to accelerator technology, from particle physics to cosmology. France has excellent human resources and technology levels in instrument science. Cooperation with France is also beneficial in this WPI initiative, and TYL and its future expansion will be incorporated as a component of this WPI initiative.

The QUP Office

The QUP Office is the dedicated administrative organization of this center. The head of the Office shall be a position equivalent to that of section chief. The work under his or her jurisdiction shall be classified into general affairs, accounting, and research cooperation. Each section shall have its organization. The KEK Administration Office will provide full cooperation to ensure the smooth progress of these operations. The General Manager of the QUP Office will also participate in the Administrative Liaison Meeting (held once a month to share administrative matters and discuss important issues), composed of managers of the KEK Administration Office.

3) -4 Research environment

* Concretely describe how equipment and facilities, including laboratory space, will be provided in a manner appropriate for a "world premier international center." Include your procedure and timing.
* Describe measures taken with regard to the research environment to sustain and strengthen research activities under conditions when international exchange is limited.
* Concretely describe how the center will consider to arrange for its researchers to participate in the education of graduate students.
* Describe new measures to improve or abolish existing systems and practices in the host institution to optimize the center's research environment.
* Describe your measures other than the above to ensure that world's top researchers from around the world can comfortably devote themselves to their research within an international and competitive environment at the center.

KEK has an unparalleled infrastructure for large-scale projects in basic research. A part of it will be offered free of charge to provide a world-leading research environment. Details are described in "6) Summary of Host Institution's Commitment.

There may be situations where COVID-19 severely restricts traveling. Even in such a case, one of the main features of this center is that it can make full use of its three satellites to carry out efficient development research. KEK has the world's most advanced DX/RX infrastructure, with a proven track record and expertise in continuing large-scale international cooperative experiments such as the B-factory, even in difficulties due to COVID-19. The infrastructure and experience will be fully utilized in this center as well.

In order to contribute to the realization of international brain circulation as one of the world's leading research centers, the center will optimize its systems and practices as much as possible and build a system that allows researchers from overseas to devote themselves to their research without feeling uncomfortable. Since this center will adopt a top-down organizational structure different from KEK as an inter-university research organization, it will require a system separate from the existing system of KEK. Specifically, the following points should be satisfied.

- As a system to ensure the leadership of the center director, a "center conference" will be established with a small number of center staff as described in 3)-3-1. The center director and members of the meeting will discuss important matters, including personnel and budget, to support timely decisions by the director.
- Take measures to allow special operations for the Center in salary and employment, using the existing system of specified fixed-term employment.
- English should be the official language for both research activities and administrative work at the center. Further work on the English environment is also discussed in 3)-2.

4) Values for the Future

4) -1 Generating and disseminating the societal value of basic research

* Describe concretely and quantitatively the center's policy for widely disseminating the results of its basic research to the general public.

Research that explores the limits of space, time, and subatomic particles awakens in public a sense of wonder that transcends science. For example, suppose the LiteBIRD satellite project, which this center collaborates with JAXA, detects the signal of inflation. In that case, it is said to be the "greatest discovery in the history of science," surpassing the two Nobel Prizes in physics awarded so far for the observation of the CMB. Its intellectual value to humankind is immeasurable. (Evidence: Report of the review committee organized by Prof. Weiss, a laureate of Nobel Prize in Physics: https://arxiv.org/abs/astro-ph/0604101.) If the results are different from the predictions, that may even transform humanity's worldview. When Super-Kamiokande announced its discovery of neutrino oscillations, U.S. President Clinton said in a speech the day after the announcement, "The discovery will have an impact on society as a whole, not just in the laboratory." We expect that LiteBIRD's observation results have a similar or even more significant impact. **If Japan can take the lead in creating such intellectual value again, it will bring confidence and pride to the people of Japan.** It will also contribute significantly to the country's continued existence as a first-class country, distinguished by other countries. The center will also collaborate with JAXA ISAS, Kavli IPMU, AIST, and other participating institutions to share such intellectual values with the public through web outreach, lectures, public presentations, and SNS. The URA and administrative staff will be in charge of outreach for continuous dissemination.

4) -2 Fostering next-generation human resources linked with higher education

* The center offers an opportune platform for establishing a research system in which new interdisciplinary domains can be created within a rich international environment. Describe concretely and quantitatively the initiatives to be taken to foster young researchers, including doctoral students, through participation in such a research system within the center.

The educational goal of this center is to develop the next generation of talents who are proficient in systems science and have deep expertise in specific fields. By learning about sensors, ASICs, computers, data analysis, and the systemology that integrates them at this center, young researchers will become scientists who can play an active role in academic posts and a wide range of industries. The center will provide training and career development support at each stage, from graduate student to post-doctoral fellow to tenure-track/tenured faculty, as described below.

<u>Graduate students</u>

The host institution, KEK, has been practicing graduate education in Japan and abroad through the Graduate University for Advanced Studies (SOKENDAI) and the Special Joint Research Fellowship Program for graduate students. In addition, a research assistant (RA) system is in operation to support these graduate students. In cooperation with KEK, we will improve the system so that researchers at this center can accept and educate graduate students. In addition, we will build an educational program for domestic and foreign students as well as Early Carrier Researchers beyond the Japanese graduate school system. We will create teaching materials that systematize quantum field measurement as a system science and hold annual quantum field measurement systemology training and practice courses for graduate students in elementary particles, cosmology, measurement science, and related fields. In the past, KEK has held a large international school, EDIT, with participants from 23 countries and has experience in holding many international schools. KEK also has a strong network with domestic and international research institutions. We will make full use of them to implement the project. As mentioned in 3-2), TYL focuses on expanding and fostering female researchers through the Women in Science Camp and the Toshiko Yuasa Award. This center will also contribute to expanding diversity in basic science in Japan through collaboration with TYL.

Unlike the cases in US and Europe, graduate schools in particle physics and related communities in Japan have not been producing a good number of dissertations on novel sensors and their systems despite their importance. QUP will be a game-changer and will contribute significantly to promoting instrumental science in general.

Young researchers

We will dispatch young researchers to the Berkeley Satellite for an extended period to foster researchers with an international perspective through the experience of "living under the same roof." The center will provide opportunities for young researchers to present their research results actively. In addition to the international research meetings of each research unit, the center will hold an international research meeting (QUP Symposium) involving the entire center to promote interdisciplinary research at least once a year. As part of our international career support, we will support young Japanese researchers to obtain research positions at partner institutions of international joint experiments such as LiteBIRD. By doing so, we will achieve long-term brain circulation. In addition, the center will establish a mentoring system by senior researchers for young researchers. It will provide strategic and psychological support to help young researchers obtain tenure-track/tenured positions at universities and other institutions and positions in industry where they can use their abilities.

4) -3 Self-sufficient and sustainable center development

* The center needs to become self-sufficent and sustainable after the funding period of 10 years. Describe the host institution's mid- to long-term plan and schedule for supporting the center development, including the reform of the host institution's organization, the provision of personnel with priority allocation of tenured posts to the center, fundamental financial support, and material support including land and buildings.

KEK will position this center as a unique organization that contributes to forming world-class activities and as an independent research organization distinguished from other research organizations within KEK. KEK will use the activities of this center as a springboard for interdisciplinary fusion and organizational reform at KEK. By becoming a center for interdisciplinary research, it is expected to create new research fields and further enhance the function of KEK. KEK will provide the necessary support to ensure that the center remains a world-class research center after the implementation period of this program is over. To that end, KEK will find the best way to reorganize roles between the KEK's existing institutions and QUP to continue QUP's function. Specific measures include positioning the center as one of KEK's research centers and maintaining the mission and identity of the center. Toward the establishment as a permanent organization after 10 years, KEK with a leadership of the Director General will assist the center to have its own financial base. Along this line, KEK will proceed toward the upgrade of the necessary facilities and acquiring the tenure positions for senior researches and technicians gradually after the sixth year.