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QUP
- A New WPI Center at KEK

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Abstract
The International Center for Quantum-field Measurement Systems for Studies of the Universe and Particles (QUP) is a new WPI center at KEK. This poster describes its overall framework, missions, uniqueness, organization, example research projects, and its systemology approach.

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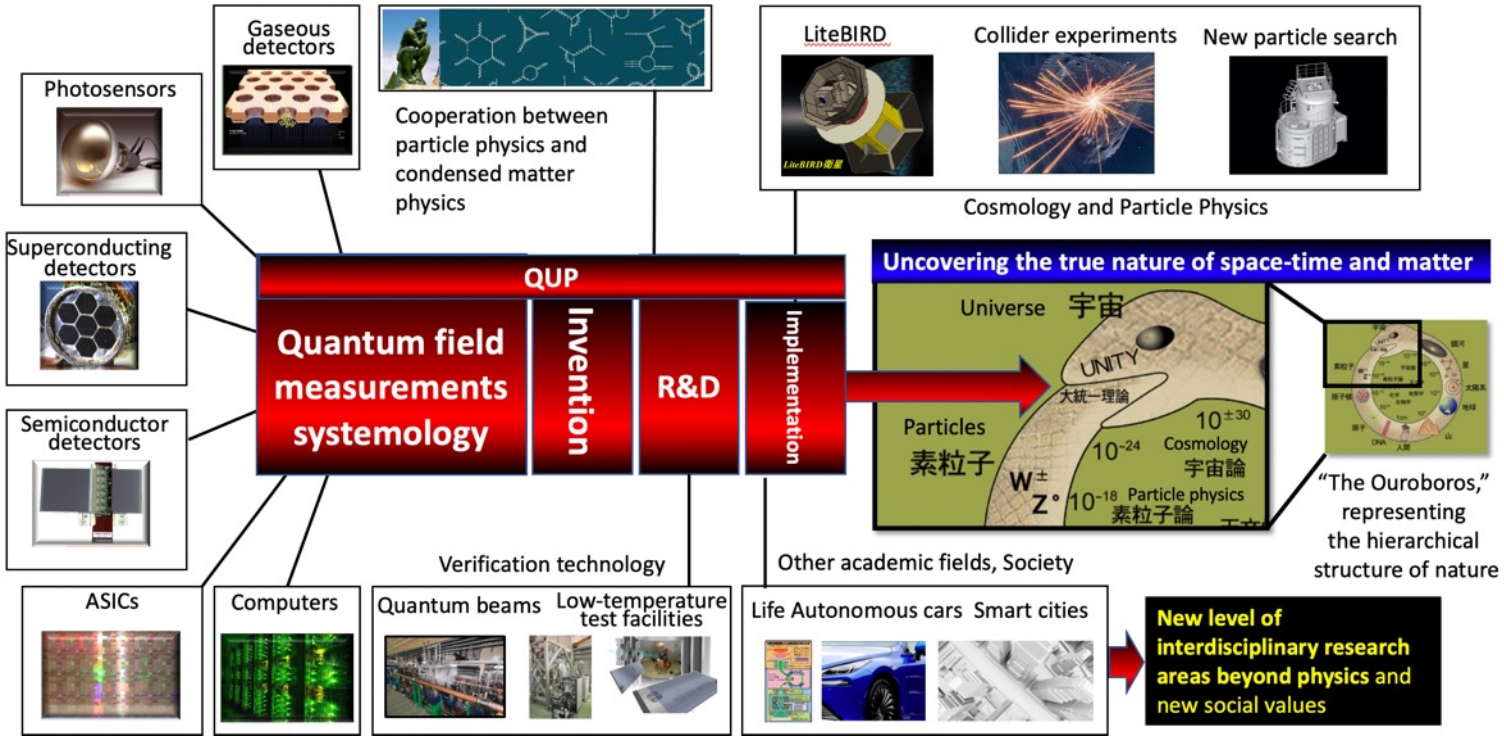
New WPI Center at KEK (from Dec. 16, 2021)

International Center for *Q*uantum-field Measurement Systems for Studies of the *U*niverse and *P*articles (*QUP*)

Overall Framework

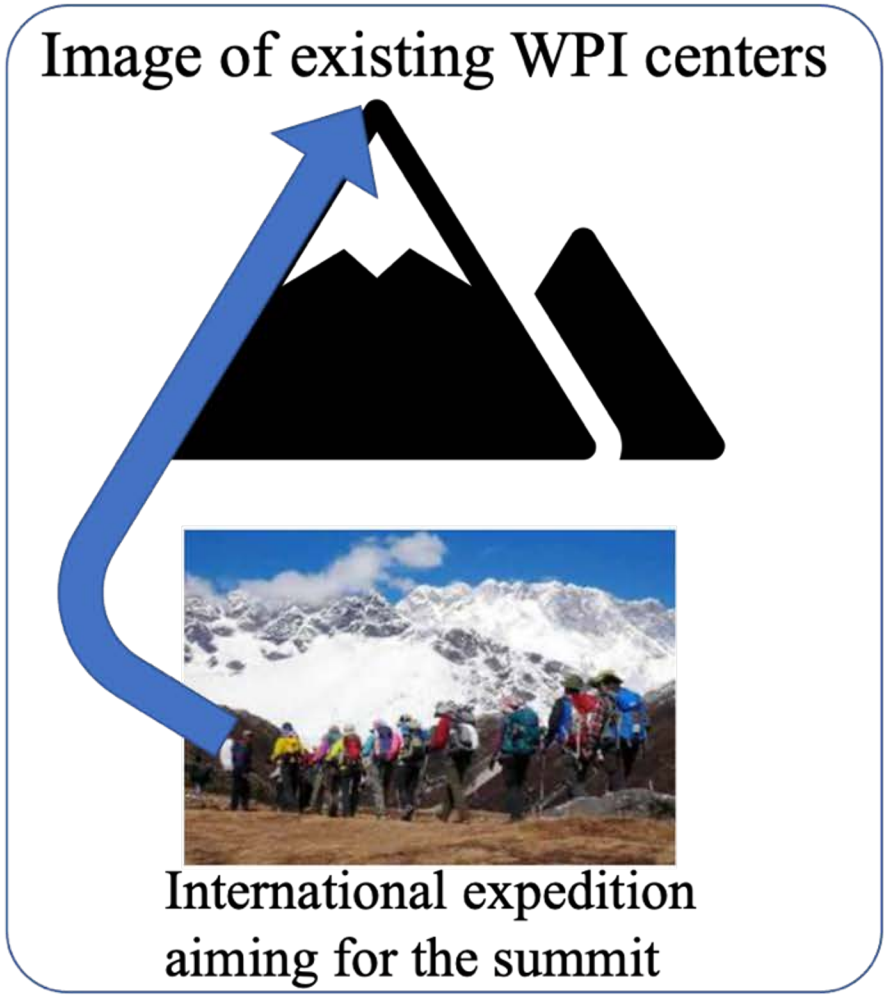


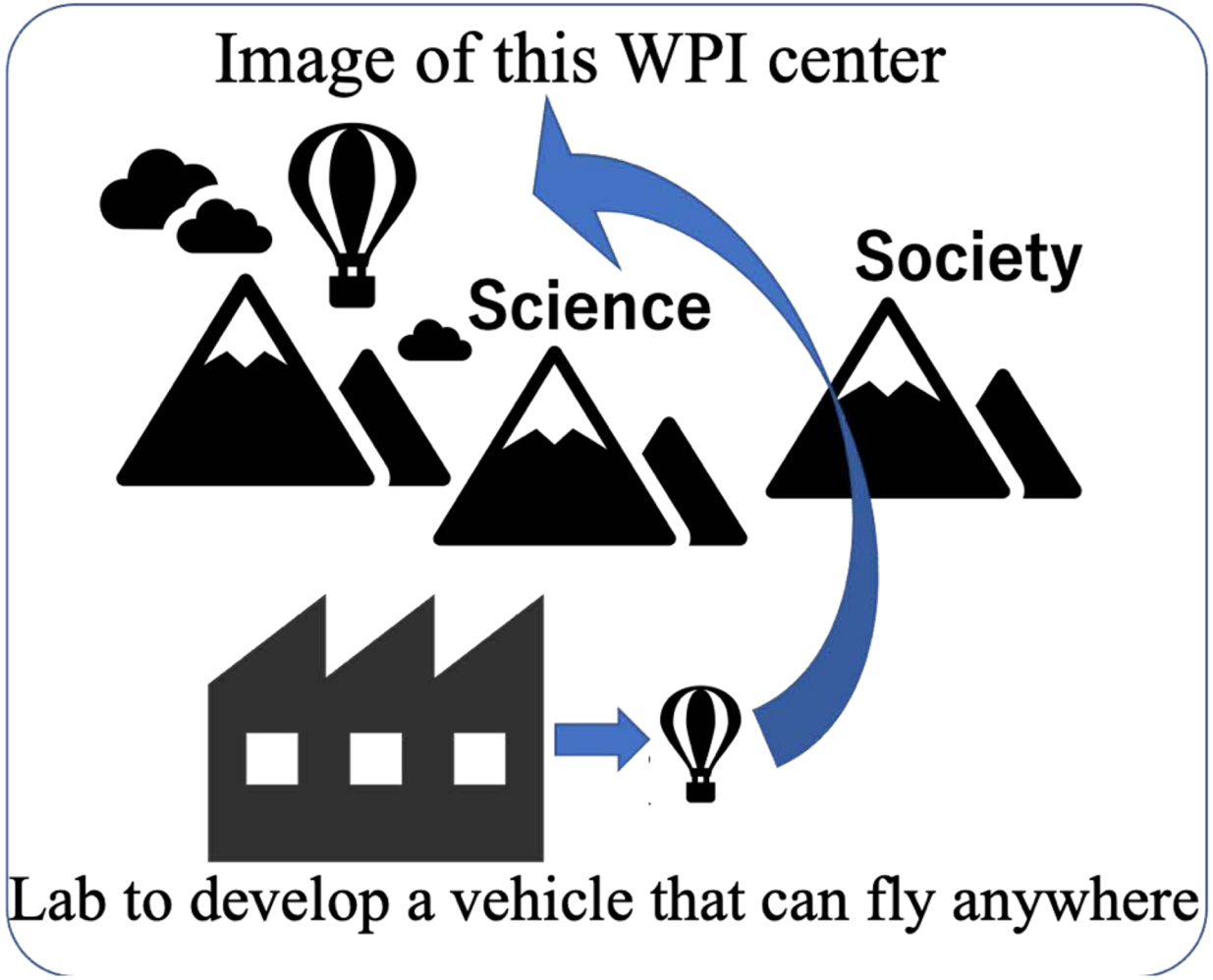
QUP's slogan: Bringing New Eyes to Humanity

Five Missions

1. **Integrate** particle physics, astrophysics, condensed matter physics, measurement science, and systems science.
2. **Invent and develop** new systems for measuring quantum fields (space-time with particles and quasiparticles created and annihilated, and associated physical quantities).
3. Bring **innovation** to measurements in cosmological observations and particle experiments, and **elucidate** the true nature of space-time and matter.
4. **Establish** a new measurement science, quantum field measurement systemology, as a science of means through the above practices.
5. 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.

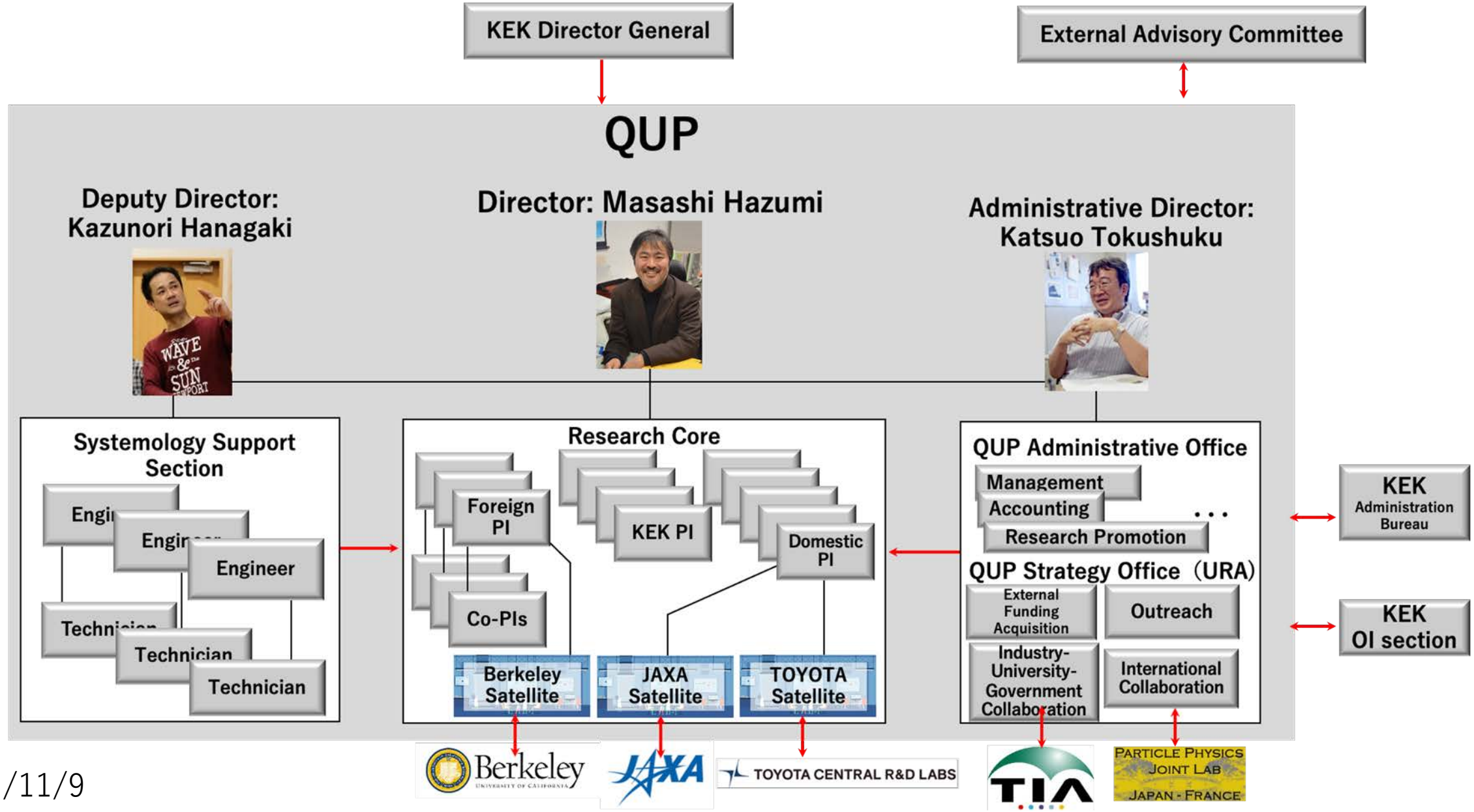
What is different from other WPI centers? - Uniqueness of QUP

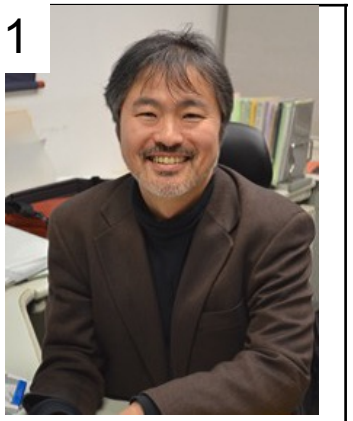
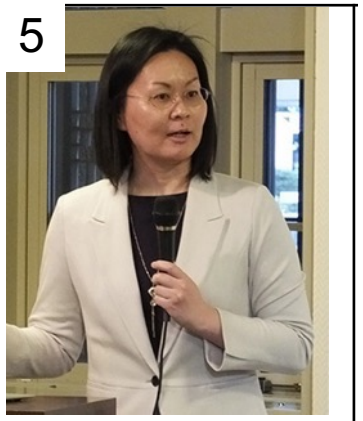
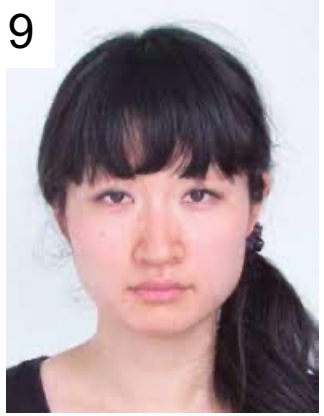




Interdisciplinary research for methodologies with multiple goals to produce academic and social values

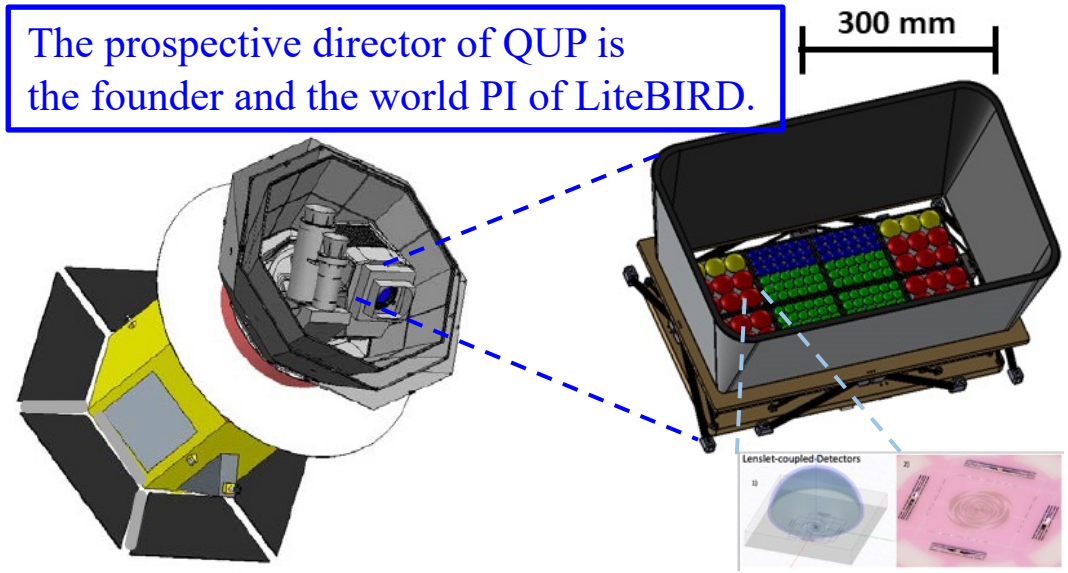
Organizational chart of QUP



Principal Investigators						
	1 	2 	3 	4 	5 	6 
	Masashi Hazumi KEK Professor	Manabu Togawa KEK Associate Professor	Masaya Hasegawa KEK Lecturer	Masaya Miyahara KEK Associate Professor	Nanae Taniguchi KEK Assistant Professor	Adrian T. Lee UC Berkeley Professor
7 	8 	9 	10 	11 	12 	13 
Daniela Bortoletto University of Oxford Professor	Maurice Garcia-Sciveres LBNL Senior Scientist	Kaori Hattori AIST Senior Researcher	Noriko Y. Yamasaki JAXA Professor	Kazunori Nakayama U. Tokyo Assistant Professor	Hideo Iizuka Toyota Central R&D Lab. Senior Fellow	Yu Nakahama KEK Associate Professor

Example Research Projects

The prospective director of QUP is the founder and the world PI of LiteBIRD.



A) QUP flagship projects

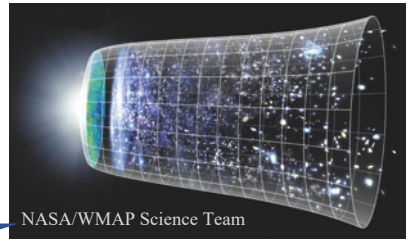
1. New superconducting detector system for LiteBIRD
   - Expected outcomes of this research
     - Discovery of primordial gravitational waves from cosmic inflation, regarded as "One of the most significant scientific discoveries of all time" – Rainer Weiss (a laurate of 2017 Nobel prize in physics)
     - Leading to future space missions in astronomy and future particle physics experiments
     - Contributing to an emerging research area of "phonon engineering" as a nano-tech game changer
2. Project Q: New particles search with a new method
   - Open call for new ideas
   - Initial selection in 1.5 years, with an additional year for the final selection
   - Bold ideas from the community are welcome!
     - Examples: new use of quasiparticles for new particle search
     - New use of quantum sensors (e.g. diamond sensors)

B) PI-led projects

- Examples: Super rad-hard system, Casimir Force Device

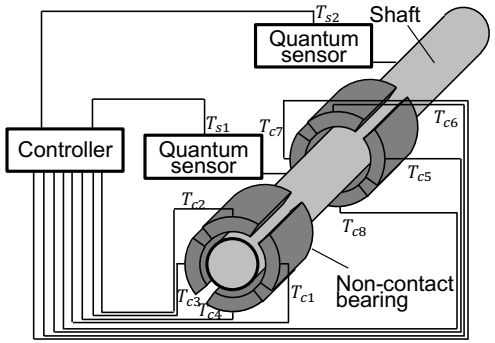
Challenges in Particle Physics and Cosmology

Four significant mysteries
- Inflation
- Missing Antimatter
- Dark Matter
- Dark Energy



New Quantum Fields as Resolutions

Inflaton, Axion, SUSY, etc.



Non-contact shaft-bearing system

Toyota group has well-established silicon carbide (SiC) technology. SiC based quantum sensors should enable the system.

Systems Engineering and Systems Science (Systemology) at QUP

Motivation

- We want/need to be faster and more accurate in doing big and complex science projects.
- We want to accumulate our know-hows efficiently, before our tacit knowledge disappears.
- We want to make our knowledge explicit (not tacit) so that others can learn it.

Approach

Systemology Studio

- Software developed by QUP's Systemology Support Section
- Aggregating existing tools (particle interaction simulators, 3D CAD software, MBSE software, etc.)
- Implementing database of technical (and even human) attributes

Systems Theory

Feedback from our practice

Concurrent design work

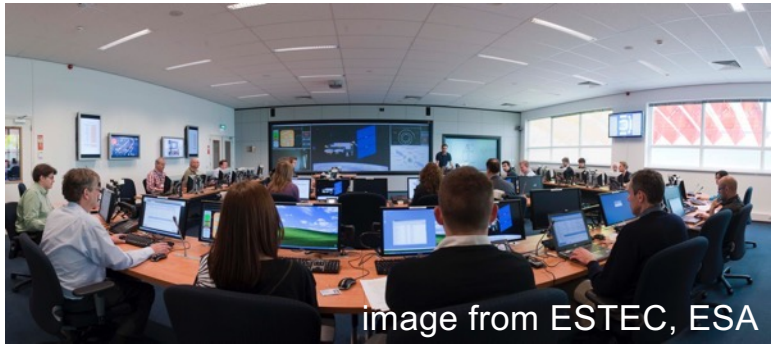


image from ESTEC, ESA

Automated design from a requirements flow

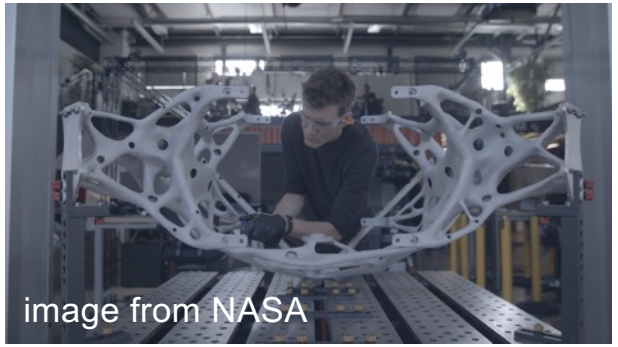
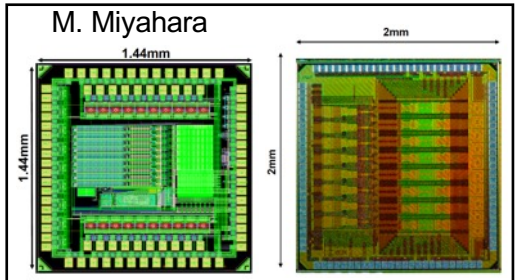
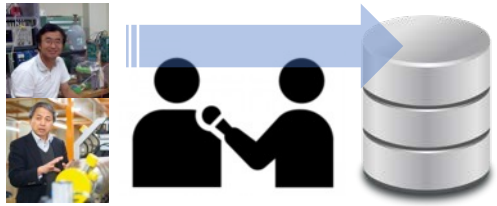


image from NASA



ASIC design (QUP PI's work)

From tacit knowledge to explicit knowledge



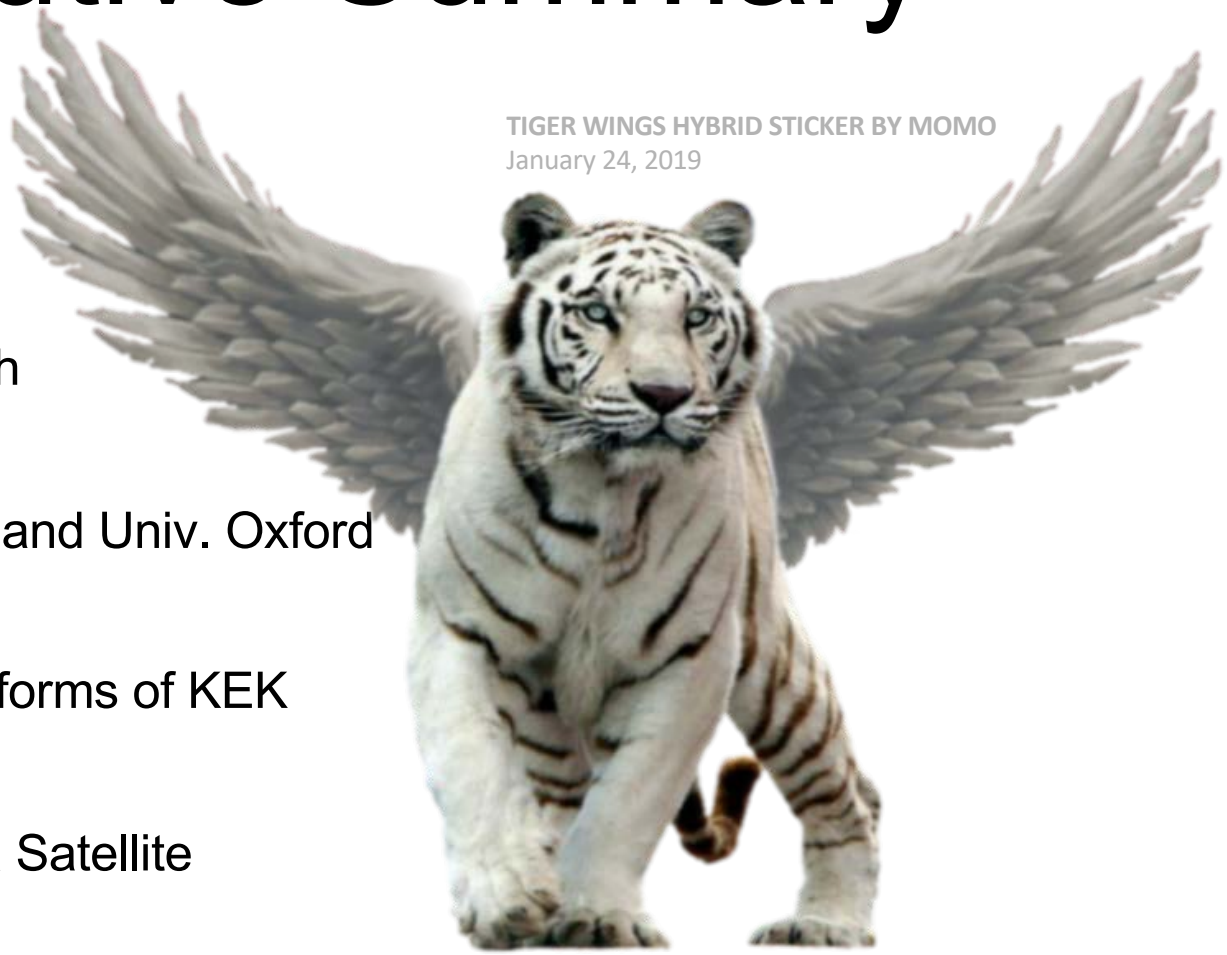
e.g. Detailed interviews to researchers with excellent development capability

MBSE Database

Systemology is our "research booster."

QUP at KEK: Executive Summary

- QUP will invent novel quantum-field measurement systems and achieve major discoveries in particle physics and cosmology
  → The Highest Level of Research Impact
- Systemology and two levels of interdisciplinary research
  → Expanding Knowledge Frontiers
- Truly international science team with Berkeley Satellite and Univ. Oxford
  → Brain Circulation
- Advancing internationalization and triggering system reforms of KEK
  → Effective, Proactive and Agile Management
- Huge impacts on social implementation with the Toyota Satellite
  → Societal Value of Basic Research
- Systemology-conscious education
  → Unique contribution to higher education
- Strong support by KEK → Self-sufficient development



With QUP, KEK will be "a Tiger with Wings."

From Press Release

https://www.kek.jp/en/press-en/202110081335/

KEK is awarded to host a new world premier international research center for quantum-field measurement systems. It is the 14th World Premier International Research Center Initiative (WPI) promoted by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) such as Kavli-IPMU.

The new center's name is the International Center for Quantum-field Measurement Systems for Studies of the Universe and Particles (QUP). It will be directed by Dr. Masashi Hazumi, a professor at the Institute of Particle and Nuclear Studies, KEK, and the PI of LiteBIRD, a space mission led by Japan Aerospace Exploration Agency (JAXA) for cosmic microwave background (CMB) measurements. He also worked in various international projects for cosmology and particle physics, including Belle at KEK.

QUP will integrate particle physics, astrophysics, condensed matter physics, measurement science, and systems science in the works of invention and development of new systems for measuring quantum fields (space-time with particles and quasiparticles created and annihilated, and associated physical quantities).

"I am thrilled about the launch of QUP. As the director, I want to support the Principal Investigators (PIs) and other researchers in taking on the challenge of making a giant leap forward. I am also delighted with new studies toward social implementation with the research cooperation of the Toyota Group," Hazumi says, "and as one of the PIs, I will also work on the LiteBIRD satellite that I initiated and is the flagship project of QUP."

The KEK Director General, Dr. Masanori Yamauchi, welcomes the new initiative, "KEK will support QUP's missions strongly. There are many research groups around KEK having great interest in the activities at QUP. Collaboration with those groups will also be beneficial. I hope that the outcome from QUP will significantly boost KEK's research as a whole."

QUP has a characteristic of the global and diverse nature of quantum-field measurement. In addition to basic science, it will promote interdisciplinary research that transcends the boundaries of industry and academia. QUP will also promote corporations with world top institutes by opening three satellite offices in the Toyota Central R&D Labs. in Aichi, Japan, ISAS/JAXA in Kanagawa, Japan, and the University of California, Berkeley in the US.

"I am exhilarated to launch a satellite of QUP at Berkeley. I believe it has great potential for making great discoveries in many fields including my field of CMB observations," says Prof. Adrian T. Lee at UC Berkeley.

PIs will join from Japanese and foreign institutes including AIST, Tohoku University and the University of Oxford (UK), in addition to PIs from KEK and three satellite offices mentioned above.

"QUP will break national boundaries and accelerate the development of novel instruments for measuring quantum fields. I am excited to start the discovery voyage with this talented team." Prof. Daniela Bortoletto at the University of Oxford says.

KEK is in the process of establishing QUP, aiming to start its activities by the end of this year.

Dr. Masashi Hazumi (left) and Dr. Masanori Yamauchi (right)