Center Director's Vision

As a researcher, I can hardly contain my excitement at the thought of the realization of this research center. My research style is to unravel the great mysteries of particle physics and cosmology using new measurement methods. In particle physics, I led the discovery of CP violation at the KEK B-factory, for which I received the 4th JSPS award from the Japan Society for the Promotion of Science. The discovery led to the Nobel Prize in Physics for Profs. Kobayashi and Maskawa. In experimental cosmology, I formed the POLARBEAR project team in Japan and succeeded in the first observation of gravitational lensing effects using polarized cosmic microwave background (CMB) alone. In each case, I felt as if I had touched the depths of nature with my bare hands. The memory of my excitement is still vivid. The source of the excitement I mentioned at the beginning of this note is the conviction that this center will bring about discoveries beyond the achievements mentioned above.

KEK promotes the mission of solving the mysteries of the universe, subatomic particles, and life by using particle accelerators. It is already recognized worldwide as an international center for accelerator science. Why is it necessary to propose a new center? What should we do to lead the world beyond other accelerator centers, such as the European Organization for Nuclear Research (from now on referred to as CERN)? I propose this center because I believe that further innovation is necessary for three reasons as follows.

The first point is that **KEK, an international center for accelerators, needs to become a global center for measurement systems**. Unfortunately, Japan is lagging in measurement systems at the forefront of space observation and particle experiments, and we are relying on the most advanced measurement systems of foreign groups for various projects. Even at KEK, the development of a measurement system to precisely observe particles produced by the accelerator has relied on individual researchers' heroic and artisanal efforts. On the other hand, international accelerator centers worldwide have already taken a more organized, strategic, and interdisciplinary approach.

Second, we need to work on new and essential research to solve the mystery of the universe, subatomic particles, and life. We do not need to tie ourselves to an accelerator to this end. Under the banner of the search for cosmic connections (the connection between the universe and elementary particles), CERN's strategic cooperation with projects such as the Antiparticle Cosmic Ray Observatory (AMS) has produced significant results in space observation. On the other hand, at KEK, space observations are still a kind of "private stores" operated by individual researchers, including myself. Some institutions conduct astronomical and space observations in Japan, but they lack the perspective of space observation that can elucidate the mysteries in particle physics. Now that the universe and subatomic particles are more closely related to each other than ever, I believe that the next scientific revolution is likely to come from cosmic connections. In order not to miss the chance of discovery, we need to take immediate action.

Third, the world of detectors is undergoing a revolution, and urgent action is needed. In recent years, new detection principles using various quasiparticles and new sensors using quantum effects have been proposed. Existing detectors, such as semiconductor detectors, also need to be upgraded to meet the requirements of the next-generation experiments. History has proven that new detector systems are the key to opening up new research in cosmology and particle physics. **These new detectors and sophisticated detector systems are collectively called "quantum field measurement systems" in this proposal. It is a new concept with two meanings: one is to measure the new quantum fields, and the other is to measure "with" quantum fields, including various quasiparticles.** The term "measurement system" means the entire device, which includes the sensor itself, the integrated circuit that extracts the signal and the computer that corresponds to the "brain" in humans.

In a nutshell, I sum up the above as **"whoever rules the quantum field measurement system rules the research on the universe and elementary particles.**" With this in mind, my vision for this center is as follows.

The primary vision is to form an unparalleled research center on measurement systems for cosmology and particle physics, where we carry out everything from the invention of principles to the execution of large-scale projects seamlessly, and to lead the world at a stroke [Center's Identity I]. International accelerator research institutes that rival KEK, such as CERN and Fermi National Accelerator Laboratory in the U.S., have their detector development groups. Still, there is no single center that can take a project from idea to execution. **This center, which will be the only one of its kind globally, will be a "full-fledged move" for Japan to take the lead in the competition with CERN and others in the field of measurement systems**. This center aims to be a place that promotes inventions for quantum field measurement systems that realize the dreams of research. Our goal is to create a measurement system that will meet the grand challenges of science rather than improve the system to pursue immediate results. We want to develop ideas magnitude better than those of the past. We lead to significant discoveries by providing an environment where researchers can build ideas and have sufficient research time at this center [Center's Goal 1]. One example of research that excites me is the systematic and exhaustive study of the interaction between the theoretically-predicted quantum fields of novel elementary particles and the various quasiparticles in the matter. It will lead to the invention of a new quantum field measurement system. Until now, the connection between condensed matter physics and particle physics has been

overlooked. However, there are various quantum fields of quasiparticles in different physical systems. These fields should be inextricably linked with the quantum fields of elementary particles in the matter. It is a vast and untouched research area, and this center will be engaging in the first thorough systematic research. 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.** I hope that this center will become the "birthplace" of future great discoveries.

In the spirit of the end-to-end research from invention to implementation mentioned above, the quantum field measurement system invented at the center will be implemented in actual projects for cosmology and particle physics [Center's Goal 2]. One example is the LiteBIRD satellite project, which aims to explore the Universe before the Big Bang and get closer to the fundamental physical laws behind it. It is a project that I proposed, and I serve as the global PI. My group is currently developing an innovative superconducting detector array with a group in the U.S. to convert the incoming CMB photons into phonons and read them with a SQUID. It is an example of a new detector using quasiparticles. This center will promote it as the flagship project. We will also propose and encourage projects for new cosmological observations and particle physics experiments based on the invention of a new quantum field measurement system [Center's Goal 3]. As already mentioned, new sensor technologies are emerging recently. We will propose new experiments by using them. Among them, we will carefully select and promote those that have the best chance of success. In addition, we will encourage the application of the new quantum field measurement system to the upgrades of existing accelerator experiments. The term "measurement system" includes data analysis methods that correspond to the human brain. The center will also aim to invent new analysis methods [Center's Goal 4].

This center will conduct **interdisciplinary research on "means" or "methodologies," not for specific research topics in particle physics or cosmology alone.** It is at the meta-level, **leading to a new level of fusion of various research areas to produce academic and social values [Center's Identity II].** The new "eyes" invented and developed at this center will undoubtedly be applied to other fields and create new social implementations and social contributions. This center will promote such social contributions by establishing a satellite at the Toyota Central R&D Labs for collaboration instead of leaving it to others [Center's Goal 5]. In addition, with the vision of global collaboration of manufacturing laboratories, we will establish two more satellites (Berkeley and JAXA) to promote collaborative development.

I want to emphasize that the above vision is based on KEK's strengths listed in the following:

- Demonstration of the measurement system can be done using the **various quantum beams provided by KEK's accelerator facility** [Center's Identity III].
- The experience and capabilities as a host of large-scale international joint experiments [Center's Identity IV].
- The extensive global human network and abilities as an inter-university research institute cultivated so far [Center's Identity V].

KEK, which already has one of the best infrastructures in the world, will establish a new WPI center by concentrating all its efforts, and it will be an unrivaled international research center. **As the overall leader of the LiteBIRD satellite project, I will make full use of my experience as a leader of about 300 researchers from 12 countries to manage the WPI.**

We want to take a systems science approach to the development of quantum field measurement systems. The systematic introduction of systems engineering and systems science (systemology) will serve as a base for building up the development process as an intellectual foundation. Recent satellite development has shown that the systematic introduction of modeling languages accelerates the accumulation of know-how as projects are described in modeling languages rather than in documents. This center will apply this method to basic science projects and generate a significant expansion of knowledge in 10 years. **Ultimately, we want to create a new field of quantum field measurement systemology as a "science of means."** This center will nurture the next generation of researchers proficient in using systems science and have deep expertise [Center's Goal 7].

Finally, I would like to describe my dream. My dream as a researcher is that the activities of this center will result in three Nobel Prizes in physics in the future. LiteBIRD will take off. A new experiment will start to search for novel quantum fields. The next Georges Charpak (Nobel Prize winner in Physics for developing a detector) will be born from this center. Finally, my dream as a person is that the research of this center will become the foundation for the happiness of humanity.