Report of the KEK Five Year Roadmap Review Committee

April 24, 2008

Executive Summary:

The KEK Roadmap Review Committee was convened by the Director General of the High Energy Accelerator Research Organization (KEK), Dr. Atsuto Suzuki, on March 9-10, 2008 in Building 4 Conference Room at KEK. The Committee was charged to review the Five-year Roadmap of the Organization and provide him with recommendations. The agenda of the meeting, the charge to the Committee, and the list of the Committee Members are found in Attachment 1, 2 and 3 respectively. The KEK Roadmap (5 year Plan) that was provided prior to the meeting is found in Attachment 4.

In addition to the general request to review the Five-year Roadmap, the Committee was charged to address a number of specific issues (Attachment 2). The Committee's deliberations followed these specific issues.

The proposed Five-year Roadmap is built on the outstanding performance of KEK in developing comprehensive accelerator based science capability in Japan, and becoming one of the important international research centers. It comprises forefront projects in the areas of nuclear and particle physics as well as material and life science. It also comprises in-house and off-site projects which are well balanced to keep the already well established international role of KEK in these areas.

The Committee considers the roadmap presented as a convincing one, and offers exciting scientific prospects in all its elements and fully endorses it.

The measurements at B-Factories have led to a quantitative confirmation of the Kobayashi-Maskawa model, which has become one of the pillars of the Standard Model. Now, this Roadmap sets the stage for a new generation of measurements at KEK-B with a 10 to 40-times higher luminosity. The Committee unanimously supports the proposed luminosity upgrade so that KEK-B can enter into the phase to probe new physics beyond the Standard Model. It should be noted that the reach of the upgraded KEK-B for new physics is complementary to that which can be provided by discoveries at the forthcoming CERN LHC in search for physics well beyond the TeV scale.

The high beam power operation of J-PARC is critical for many sciences using the new proton synchrotron, and its timely power upgrade again receives the Committee's strong endorsement. Following the pioneering achievement of K2K (KEK-to-Kamioka), T2K (Tokai-to-Kamioka) will permit a new generation of long baseline accelerator based experiments, by providing a unique opportunity to maintain a world-leadership in this field. The high power of the accelerator, thus a high yield of secondary particles, can open new horizons in particle, nuclear, and material sciences. Examples for the particle physics opportunities include rare K decays and the search for T violation in semi-leptonic K decays and muon physics such as muon-electron conversion and the anomalous magnetic moment of the muon, all of which probe the fundamental nature of elementary particles. There are complementary opportunities in nuclear physics such as systematical studies of hypernuclei. In addition, the high power J-PARC will offer an internationally competitive and complementary set of tools for materials characterization and research. The enhanced program at J-PARC, however, points to needs for further development of its experimental facilities.

The Committee found that the material and life science component of the KEK roadmap offers a very compelling future vision which would add significant strength to the overall growth of KEK, contribute greatly to Japan's R&D, relevant to a number of areas such as biomedicine, energy and the environment, and take advantage of important emerging synergies for novel accelerator based developments within KEK and several outside partnerships. Perhaps most importantly, KEK should seize the opportunity to develop a next generation x-ray ERL, becoming a world leader in this important new direction. A prototype ERL is the first and most important step along this pathway. KEK has the talent, the infrastructure and the established program in synchrotron science with the PF and PF-AR rings, instrumentation and user activities upon which to build the machine. It is essential to sustain, hopefully increase, this level of effort and support (and thus budget) so as to continue to provide both the important resources in synchrotron radiation for the Japanese user community and provide the "bridge" to the future ERL light source. The planned new Center for Materials Structure is another important element of building a transformational science program that will underpin the scientific applications of the current and future machines. Simply stated, a strong program at PF, aggressively taking steps toward the ERL will give KEK a world leadership position in photon science.

KEK has significant involvement in the LHC at CERN. In addition to the in-kind contribution to the collider construction, Japan made very important contributions to the ATLAS detector, not only the in-kind contributions through detector parts but also through scientific and technical support with a number of physicists stationed at LHC. Now that the commissioning of the LHC is in sight, the Committee urges KEK to continue to support this effort, participating in the research at the energy frontier. In addition to the exploitation of the investment done to date, it is advisable for KEK to continue its participation in the upgrade of the LHC to maintain its technical expertise and to harvest exciting physics in the future.

Japan has already made significant contributions in many areas of the ILC R&D and is a major player in much of these efforts. The ATF has been and is the key facility for the ILC design as well as an efficient test bench of the devices needed for the ILC. The test beam line ATF2 is coming to the commissioning stage this year. This is a unique facility for the test of the ILC final focus system. The construction of test facility for the superconducting technology, STF, is showing steady progress towards the system test of the RF unit in the next couple of years, which is believed to contribute very much to the final design of the ILC. KEK also represents the Asia region as one of its prime movers. The support the project receives from Japanese major industries is of great significance. Therefore, the ILC R&D is naturally an important part of the KEK Five-year Roadmap, and as such the Committee strongly encourages KEK to maintain this course, with particular attention toward the further study of very low emittance beam control, superconducting rf, and industrialization of accelerator components including superconducting cavities.

As a whole, the scientific themes of the roadmap present an excellent and challenging but feasible program, given the experience and dedication of the staff of KEK. The unanimous conclusion of the Committee is that the basic parts of the goals of the projects, as outlined for the next five years, can be achieved within the budget presented by the directorate of KEK. It is, however, obvious that the international standing of KEK demands a more ambitious schedule and scope, consequently, stronger efforts in most areas. This applies to all three areas mentioned above but in particular to the high priority projects which are the upgrade of KEK-B, the ILC efforts and the ERL project, in order of priority as pointed out to the Committee by the KEK management. Specifically, the Committee urges KEK management to pursue the possibility of reducing the shutdown period for the KEK-B upgrade from three years to possibly two, continue and enhance the ILC R&D effort including industrialization, and ERL R&D with a development of Compact-ERL with energy of ~200 MeV where the critical test of beam dynamics can be performed in preparation for the 5 GeV machine.

The human resources to support the Roadmap program are available at KEK, with excellent expertise, in some cases even unique in the world, which were cultivated through the past successful endeavors. However, they must be adequately supplemented by additional funding in order to achieve more ambitious goals. Here, the Committee also notes that it is very important for the management of KEK to seek an increase in the funding for these projects beyond the absolute minimum which the budgets represent at this moment. Again, this represents the unanimous opinion of the Committee. Considering the synergistic relationship of accelerator works involved in the Five-year Plan, a consolidation of accelerator groups should be studied to enhance the efficiency in the R&D, upgrade and construction work involved.

More detailed reports, responding to the charge given to the Review Committee, are in the subsequent sections of this report.

Charge 1: Evaluate the scientific roles that KEK has taken in the past decade from the perspectives of the world-wide accelerator-based science community, especially in the following respects:

- **Studies of CP violation and heavy flavor decays at the B-Factory:**

  Over the past decade, KEK has been leading the world in the study of CP violation and heavy-flavor physics, thanks to the outstanding performance of the KEK-B accelerator and the excellent achievements of the collaboration working with the BELLE detector.

  Soon after commissioning, the KEK-B accelerator rapidly achieved a large luminosity useful for physics, enabling the BELLE collaboration to start cutting-edge analyses. Subsequently, the accelerator went on to achieve record luminosity, exceeding the design by a factor of about two. One of the key innovative steps to reaching this luminosity was the winding of solenoids to combat the electron-cloud effect. In addition to achieving high peak luminosity, KEK-B was able to obtain high integrated luminosity by continuous injection and luminosity leveling. Daily integrated luminosities have exceeded 1.3/fb. A promising step towards the future has been the introduction of crab cavities, which offer the prospect of a substantial increase in luminosity. This and the other successes of the KEK-B machine group lay a firm technical basis for the ambitious KEK-B upgrade project.

  The BELLE collaboration at KEK-B has had many important achievements in B physics, notably in measuring CP violation and establishing that the large CP violation seen in B meson decays is largely due to the Kobayashi-Maskawa model. The first important result from BELLE was the measurement of sin $2\phi_1$ in B to K J/ψ decays, which demonstrated that CP violation is large in B decays. This measurement has subsequently matured into a precise determination that is an important constraint on the unitarity triangle. BELLE has also measured ϕ_1 in B to s transitions, where intriguing puzzles persist. BELLE has provided valuable measurements of the other CP-violating angles, ϕ_2 and ϕ_3.

  These measurements have led to a quantitative confirmation of the Kobayashi-Maskawa model, which has become one of the pillars of the Standard Model. The stage is now set for a new generation of measurements at the upgraded KEK-B accelerator to probe new physics beyond the Standard Model.

  In addition to these world-leading measurements of CP violation in B decays, BELLE has made several other important measurements, including b to $s\gamma$ and $d\gamma$, b to s l^+l^- and B to $\tau\nu$ decays. Also noteworthy have been the observation of mixing in the neutral D-meson system and the discovery of new mesons containing heavy quarks, including an excellent candidate for a four-quark state.

- **Long Baseline neutrino experiment:**

  Japan has a tradition of excellence in the field of neutrino physics, as recognized by the Nobel committee, based, in particular, on the construction of the large detectors, first Kamiokande and then Super-Kamiokande, at present a unique facility.

  Experiments at Kamiokande have definitively confirmed the existence of neutrino oscillations by observing them in solar neutrinos and atmospheric neutrinos. Directly relevant to the present roadmap are the successful preceding experiments: KamLAND, measuring the disappearance of anti-electron-neutrinos coming from nuclear power-plants, and K2K, the latter being a first long baseline accelerator experiment showing muon-neutrino disappearance.

- **Material and life science program at PF/PF-AR and at J-PARC**

  The programs in materials and life sciences at KEK utilize accelerator-based tools for a broad and innovative program supporting the research programs of a large number of university and industry scientists. The invention of powerful instruments with ancillary equipment and technical support staff are key aspects of these facilities and coupling to user communities essential.

  There are a number of key advantages at KEK for Japanese science, one of which is the juxtaposition of science and innovative technology as seen in PF for photons and KENS innovation leading to J-PARC for neutrons and muons. Here, one should note the importance of having science drivers at KEK who lead instrument and technique development. The second is the track record of developing and effectively serving the user community; i.e., special university linkages of KEK and flexibility in the KEK budget for these interactions of strategic importance for neutrons, photons and muons. Lastly, one notes an importance for Japan to have had KEK as the agent to bring accelerators into broader areas of science apart from high energy and nuclear physics.

  <u>Photons:</u>

  The Photon Factory (PF) at KEK began operation of a 2.5 GeV ring in 1983 as one of the world's first dedicated sources of synchrotron radiation. Subsequently the TRISTAN Accumulation Ring was also operated as a second ring for synchrotron science (PF-AR). An International Review Committee visited in 2006 and reviewed operations and plans for the PF. The Committee found that PF has served the scientific community in Japan as well as internationally in an exemplary manner. A main reason for success over such a long time has been a continuous improvement program with major upgrades, improving accelerator performance and modifications to additional straight sections for insertion devices. Among the notable activities were the developments of various types of novel in-vacuum insertion devices including the small gap undulators. On the science and application side, PF serves a growing scientific user community that currently numbers around 3,000 users. The users come broadly from universities, national laboratories and industry both within Japan and internationally. There have been significant achievements across a wide area of chemistry, physics, biology and condensed matter sciences. International collaborations have been a very distinguishing feature - for example, with the Australian consortium beam line. An especially noteworthy recent example is the recent development of a world-class program in structural molecular biology, which has been enabled through the formation of a Structural Biology Research Center. The SBRC, led by its highly motivated director, has brought significantly enhanced funding and resources to PF (about $25M over 5 years and 20 people) and strongly engaged the bio-pharmaceutical industry in their utilization and reliance upon synchrotron radiation for drug discovery.

The PF is an important and significant facility as the premier source of soft x-rays in Japan. However, over the past 2 years, the PF ISAC has found that the declining budget situation at PF and very limited manpower for supporting experiments and the beam lines has been very limiting. This situation, where only 39 scientists support more than 50 beam lines, is leading to reduced innovation in technological developments and scientific productivity, lower efficiency in utilization and a reduction in the effectiveness in bringing in new communities of users. The situation is strongly unfavorable when benchmarked internationally where the norm is well over one scientist per beam line and for the premier beam lines having the most advanced capabilities the range of 4. While part of this problem can be addressed by reducing the number of operational beam lines as is currently being done by PF management, on balance additional scientific staff are needed for innovative work that will keep PF at the forefront, especially as they aggressively move toward new scientific areas like advanced imaging and time resolved studies and prepare for the science which will be enabled in the future by an x-ray ERL. Noting the continuing importance of soft x-rays until their availability from the ERL and a smooth transitioning needed for the photon source to upgrade and new source, it is felt that scientific/beam line staffing numbers should not be further reduced at absolute minimum, and every effort should be made to gradually increase this number.

Neutrons and Muons:

KENS (KEK Neutron Science facility) has long been recognized world wide for its pioneering instrument developments in spallation neutron scattering and muon methods and their use for materials science. Its success was the basis of new sources in USA (IPNS), UK (ISIS) and recently US (SNS at Oak Ridge) and back in Japan (J-PARK). MUSE (Muon Science Experience facility) also has been well known to be the first muon factory established in 1980, which was followed by the moun experimental facility jointly established with RIKEN in UK (ISIS), Switzerland (PSI) and Canada (TRIUMPF). KENS and MUSE supported more than 400 and 100 users, respectively, each year as the inter-university organization until 2005 when the PS was shut down. After that both facilities took care of their users by making arrangement for them at overseas facilities.

In 2004 KENS had 15 beam lines and 15 research collaborations. In the inter-university research program, the spread of interest, much in very new areas, was: polymers and biology - 15%, spin systems - 11%, liquids and amorphous materials - 28%, and crystal structures and dynamics - 32%. The number of proposals had doubled to 200 between 2000 and 2005 (close-down of the facility). In the similar period, MUSE had 4 beam lines to develop the inter-university research program in the following research fields: magnetism 31%, superconductivity 30%, muon as a hydrogen 18%, chemistry 3%, atoms and molecules 5%, life science 3%, and technical development 10%.

- **R&D for future accelerators**

KEK has a long history of accelerator R&D. In colliders, this goes back to the development of SRF cavities for TRISTAN, and is continuing through KEK-B which has led the world in high luminosity electron colliders. Most recently, the KEK-B Group has brought on-line the crab cavities, a world first. J-PARC is an extremely innovative set of machines which simultaneously addresses a wide variety of user communities. The ILC research at KEK, both the superconducting cavity research and the research at the ATF, is world-class. This is the backdrop to the accelerator R&D required to support the ambitious goals of the KEK Roadmap.

The following Table shows the areas of R&D required for each project in the Roadmap.

	J-PARC	KEK-B	PF	LHC	ILC	ERL
Superconducting RF acceleration		X			X	X
Superconducting crab cavity		X				
Superconducting magnets		X		X		
Beamlines	X					
Power upgrade	X					
Energy upgrade	X					
Vacuum chamber components		X				
IR upgrade		X				
Beam dynamics	X	X				X
Lattice design		X			X	X
Beam simulations	X	X				
Fast kicker	X				X	
Diagnostics	X	X			X	
Beam instabilities	X	X			X	
CSR		X			X	X
Short pulse development			X			

(photons)						
Laser-Compton backscatter					X	X
Final focus					X	
Small emittance, high current gun						X
Laser						X

The main areas which appear to be heavily subscribed are as follows:

- Superconducting RF – this is an area where KEK has a large amount of experience and four different groups. There appear to be sufficient resources to cover the need.
- Beam instabilities and CSR – this is a hot area of study worldwide and KEK is participating at a very high level.
- Beam dynamics and lattice design – these are areas where KEK has a depth of experience.

There do not appear to be major conflicts between the R&D projects discussed in the presentations. The operation and improvements to J-PARC and KEK-B may evolve and impact the ability of the staff to address the R&D topics. However, at this time, it is impossible to guess what problems will come up. The KEK staff has shown that they are fully able to react quickly and address any such problems.

Overall, there appears to be sufficient capability at KEK to fulfill the R&D program presented, and the ability of the KEK staff to carry out the R&D is unquestioned.

Charge 2: Evaluate the strategy described in "the KEK Roadmap" particularly in terms of their competitiveness and complementarity for:

- **Particle and nuclear physics program**

In particle and nuclear physics, KEK's dual future task will be to develop its world-leading role in flavor physics, including B physics, neutrino physics, K physics and muon physics, and to play a prominent role at the energy frontier, in particular also in the ILC efforts.

<u>KEK-B</u>:

Although the Kobayashi-Maskawa theory of CP violation has been confirmed by numerous experiments, important questions remain:

- Are all experiments consistent with a single set of parameters in the Cabibbo-Kobayashi-Maskawa (CKM) matrix?
- If deviations from the CKM pattern are observed, can they be interpreted in terms of specific sources of new physics?

- Is the CP violation predicted in the Kobayashi-Maskawa theory the only observed form, or are there other manifestations?
- Can the origin of non-zero baryon number in the Universe be understood?

Such questions make it imperative to pursue further the study of flavor physics in the controlled and low-background environment provided by asymmetric e^+e^- collisions at KEK-B. The Roadmap Review Committee strongly supports the proposed upgrade of KEK-B by more than a factor of 10 in luminosity, from its present record of 1.7×10^{34} $cm^{-2}s^{-1}$ to a planned luminosity of 2×10^{35} $cm^{-2}s^{-1}$, noting that it would be an important step in fulfilling this goal. It would allow numerous studies such as:

- Reconstructing B mesons as tags requires roughly 10^3 as many events as the corresponding untagged studies, given tagging efficiencies of order 0.1 %.
- Rare decays (e.g., B to X $\mu^+\mu^-$) need to be seen in sufficient numbers to enable measurements of Standard-Model predictions in the presence of new physics.
- Individual decays involving b->s transitions need to be studied in sufficient numbers to reach errors of less than a few percent in the effective value of sin $2\phi_1$.

The reach of the KEK-B upgrade for new physics is complementary to that which can be provided by discoveries at the forthcoming CERN LHC. If the LHC discovers signs of new physics at the TeV scale, studies by KEK-B will be important to determine its nature. If no such signs are seen by the LHC, then the KEK-B upgrade's reach for physics well beyond the TeV scale will make it a premier exploration tool.

With 10 ab^{-1} foreseen after 8 years of embarking on the KEK-B upgrade, including an initial three-year shutdown, the time scale for such an upgrade becomes uncomfortably long, with competitive pressure from hadronic production of beauty particles at LHCb in certain areas. Nonetheless, the two programs complement each other well, with upgraded KEK-B providing a low-background environment and excellent sensitivity to all types of particles, while LHCb enables the study of B_s mesons and b baryons.

We believe that the exciting physics program of the KEK-B upgrade will attract a large community of experimental physicists, and welcome the plans to broaden further the international participation in the KEK-B experimental program.

The Roadmap Review Committee also endorses the Belle Program Committee's recommendation that every effort be made not only to speed up the upgrade, but to continue with its progress toward an eventual luminosity of at least 8 x 10^{35} $cm^{-2}s^{-1}$, enabling the machine and detector to reach their full potential. The main obstacles to this program are available funds and manpower, both for the collider and the Belle Detector. It will also be helpful to demonstrate at an early stage that the crab crossing scheme provides the anticipated factor of 2 to 4 in increased luminosity. Options to maximize the luminosity using other techniques should also be studied.

T2K:

Since the general picture of neutrino physics has now been established, the next goal is to measure or improve the measurements of the various parameters, most notably the so-called θ_{13} angle, for which only an upper bound from the previous Chooz experiment is known.

If this angle is large enough, this will open the possibility, in the longer future, to try to determine the CP-violating phase in the lepton sector, the Grail of this neutrino physics, which could possibly account for the disappearance of anti-matter.
The new J-PARC accelerator complex constructed by KEK and JAEA, together with the existing Super-Kamiokande detector, will permit a new generation of long baseline accelerator experiments. The T2K experiment, to which KEK gives an essential contribution, thus provides a unique opportunity to maintain a world-leadership in this field.

Concerning the determination of the θ_{13} angle, the potential competition comes from reactor experiments (most notably Double-Chooz and Daya Bay). In this respect, only Daya Bay claims to be able to achieve the same ultimate precision as T2K. However, long baseline accelerator and reactor experiments do not measure the same physical quantities. Therefore, they should be considered, to a large extent, more as complementary than in direct competition. In particular, T2K could observe electron-neutrino generation unlike the other experiments.

A more direct competition could come from the US Nova experiment, but it has now been delayed. As a consequence, provided that the schedule of the T2K experiment is not altered, T2K will be the world-leading experiment in this extremely important field of research, and should be able to achieve its ultimate goals. The Roadmap Review Committee strongly supports the upgrade of J-PARC to the highest power achievable and urges KEK to maintain its schedule.

Finally, if θ_{13} is large enough, the question of a larger detector (Hyper-K or large argon detectors?) to measure the CP violating phase will naturally arise and R&D on such detectors should be pursued. In addition, such a detector would be important for other physics goals like the study of proton decay.

We appreciate the fact that the T2K experiment is strongly supported by international collaborations.

J-PARC physics:

J-PARC has the potential to provide a very diverse range of opportunities in particle and nuclear physics. However, in order to exploit fully these opportunities, it will be necessary to develop further the J-PARC experimental facilities. Examples of the particle physics opportunities include rare K decays and the search for T violation in semi-leptonic K decays, and muon physics such as muon-electron conversion on nuclei and the anomalous magnetic moment of the muon. There are complementary opportunities in nuclear physics to study systematically hypernuclei. The Committee urges the KEK and J-PARC management to develop a comprehensive research program at the forefront of high precision physics. (See response to Charge 4.)

ATLAS:

The CERN LHC will soon open the exploration of particle physics at the TeV energy frontier. Prime objectives will be to clarify how electroweak symmetry is broken, e.g., by a Higgs boson, and to discover what physics may accompany it, such as supersymmetry or extra dimensions.

KEK has played a key role in coordinating the work by a team of 90 physicists from 15 universities to prepare essential components of the ATLAS detector at the LHC, such as muon chambers and the Silicon central tracker. This team is now poised to reap the physics benefits from this large investment. An important tool will be the ATLAS Tier-2 computing centre at the University of Tokyo, and the KEK ATLAS group should work with the University of Tokyo group to coordinate Japanese analysis activities.

In parallel, it will be necessary for the KEK group to lead the upgrade on the ATLAS detector that is expected to begin in a few years. This work should proceed together with work on the LHC accelerator upgrade, both with strong KEK participation.

In parallel with the high precision physics program at J-PARC, the Committee strongly approves the plan to engage in the LHC and ATLAS activities and their upcoming upgrade, as the high energy frontier physics program.

ILC:

Numerous regional and global workshops and studies have established the physics case for a Linear Collider. The ILC technology has been proven to allow access to an energy range from 200 GeV up to around 1 TeV. In a nutshell: The key scientific objectives of the ILC will be to study Standard Model processes and new physics signatures with unprecedented precision, complementing well the discoveries and studies performed at the LHC.

KEK has been playing a key role in the world-wide accelerator activities for the ILC in several areas. These include the development of superconducting cavities, where it is one of the leading labs in high gradient developments, but also active in transferring knowledge to industry and in preparing to establish mass production. Also, KEK has been playing a crucial role in developing a detector concept for the ILD as well as in performing detector R&D at the forefront of today's technology. The detector concept is based on a large gaseous tracking volume and highly granular calorimetry.

The Committee strongly endorses the plan to engage in these global efforts: namely, accelerator R&D, detector development, and project coordination toward the global project, ILC, aiming at the frontier of high energy and high precision physics.

Design, fabrication, and test of superconducting cavities have been carried out using the Superconducting RF Test Facility (STF), a significant investment that began in 2005. The plan includes STF1 (2005 – 2008) to develop infrastructure and build and test 4 cavities in a short cryostat; STF2 (2008 – 2010) to develop ILC Main Linac RF unit and commission it in 2011; and STF3 (2009 – 2013) to develop industrialization technology and fabricate one additional RF unit by the developed industrial production technology.

For a number of years, the KEK Accelerator Test Facility (ATF) provided the international ILC community with tools to study ultra-small emittance beams. The result achieved there is phenomenal, succeeding in damping of electron beams to the emittance close to that needed for the ILC. In the second phase of the facility (ATF2), with the damped nano-scale beam extracted from ATF1, it will serve as a miniature ILC beam delivery system, a truly global project in support of the Global Design Effort (GDE).

Another very important contribution to the next lepton collider project are the electron cloud studies performed at KEKB, one of the few places world wide where such studies can be done.

In addition to the technical participation outlined above, the KEK staff is playing a prominent role in the coordinating and steering efforts for the ILC within the Global Design Effort (GDE). In summary the efforts of KEK are highly visible in all aspects within the global ILC project, and they are crucial to the success of this project.

The precision studies will be enabled through the high luminosity and clean environment expected at the ILC but can be carried out only if the detector is designed for high precision and small systematic errors.

Most recent developments concern the merging of the KEK driven and the European driven detector concepts into a single concept study, the ILC detector concept. This enhances not only the already highly visible role of KEK in the global ILC efforts but also guarantees much closer work of Asian groups with European groups concerning R&D, software simulation studies, and concept development.

In summary, KEK is playing a highly visible and acknowledged role in innovative detector studies for a future electron-positron linear collider. It is leading the activities in the Asia-Pacific area, and it plays a prominent role in coordinating the world activities concerning detectors through the Research Director within the ILC GDE.

The detector activities are well placed to be combined with the KEK program in the generic detector R&D which would maximize synergies within the laboratory.

- **Material and life science program:**

  <u>Photons:</u>

  The choice of an X-Ray ERL for the future upgrade of PF is very exciting and appropriate for the future of KEK and Japanese Photon Science. It fits materials and life science's advanced demands for ultra small and ultra-fast time resolution, and the upgrade to ERL is not incremental but is transformational. The plan is built on KEK's accelerator expertise, which is applied to fulfill broad scientific needs of the nation as well as those of Asia and the World, it preserves and enhances PF's world-leading history and embedded user community. From the scientific research point of view, the ERL light source complements the strategy to have neutron/muon source at the world leading J-PARC which built on the strength of KENS and MUSE, and complements Spring-8 and the XFEL in Harima. The ERL approach is endorsed in other parts of the world also as seen in proposals in US and Europe, and as the National Academy report in CMMP endorsed. In fact KEK is uniquely poised to develop this national (if not regional) center of excellence with its high level of accelerator capability including superconducting RF technology.

  The development of the 5 GeV ERL light source requires a firm commitment from the KEK management and an aggressive pursuit of ERL technology R&D.

  - We strongly recommend underlying accelerator development of a ~200 MeV ERL to test key challenges such as high current, low emittance preservation, beam dynamics, and energy recovery issues.
  - The focus of the R&D effort associated with the Compact-ERL development should be to be ready to make a construction proposal for an X-ERL in the next budget cycle.
  - The use of such a machine as a user facility e.g., for Tera-Hz science, comes later and can be considered as part of the next proposal for the X-ERL.
  - To ensure success, adequate manpower must be allocated to the ERL project – numbers shown (25+ FTEs) look appropriate for Compact-ERL but not for X-Ray ERL design, and must be increased in the latter three years of this budget period. We understand that many of the additional staff will come from the KEK Accelerator Laboratory, which we applaud.
  - Considering the synergy between this R&D and that needed for ILC, KEK management should seriously consider combining efforts of the Accelerator Laboratory and the PF Accelerator Group to pursue this effort.

  During the five year period it is critical that PF and PF-AR continue a vibrant research user program, and that developments oriented towards the future continue to occur

- We resonate with the plan to focus on key areas but feel that PF scientific staffing must be increased as noted in the Charge 1 response.
- A great example of such key areas is soft x-rays which couple to areas of excellence in correlated materials and national needs.
- Efforts to develop a center of excellence in structural biology, the Structural Biology Research Center, have been very successful with broad industrial impact.
- The Committee strongly supports the establishment of a Structural, Materials Research Center recruiting a motivating Director, as like that for the Structural Biology Research Center. The Center would benefit neutron, photon and muon applications, would expand to other areas, and would include simulation and theory. We strongly endorse the orientation towards science as the overarching drivers, rather than instruments.
- We recommend a scientific focus on imaging and ultra fast science that fits the future vision. This would position KEK and user community (and universities) to take aggressive advantage of science opportunities.

The Committee, recognizing that Japan has and should continue to have two centers of excellence in Photon Science, advises that Japan convene a national level review, coordinating developments to benefit the larger community and to ensure world leading status.

<u>Neutrons and Muons:</u>

As tool for research complementary to the light source, the strength in neutron scattering capabilities offered by J-PARC must be realized.

The contribution of KEK and JAEA staff to the design and construction of spallation neutron targets, moderators, beam lines and instruments over the last four years represents a remarkable scientific and technical effort. The muon facility including the muon target, guide lines and guide magnets are almost completed by the KEK muon team, and is expected to meet the first proton beam injection scheduled in May 2008. KEK staff have based themselves on the Tokai campus accepting and resolving the challenges of constructing a new facility and producing solutions to many problems from their deep understanding of neutron scattering technology and aspirations to make new instruments unsurpassed in quality elsewhere in the world.

Investment in J-PARC for materials and life science requires a strong operating and upgrade budget for 2009-2013. The agreement of the partners (KEK and JAEA) to an operating budget of 187 Oku yen for the next four years will be a major step forward for realizing the potential of the $1.5 billion invested so far and the commitment of the whole J-PARC staff over the past six years to the project. This budget was estimated by the International Advisory Committee of J-PARC as the minimum to successfully enter the operational phase - promoting external use, ensuring that adequate spares for continuous operation exist and resolving the teething problems of the new accelerator systems.

Facility, instruments and techniques:
The instruments for operation in 2008-2009 will attract users in physics, chemistry, biology, and material science and are capable of giving publishable results within the first year when the proton power on target will probably not exceed 100 kW. As for neutron experiment, there is a risk to operation in the spares situation and in the technical support, particularly for ancillary equipment, cryostats, controlled atmosphere, preparative laboratories and technician support have to be built up. The muon facility has only one beam line that was built with the superconducting magnet from the old KEK. It is crucially important to grade up the first beam line as well as to develop a unique ultra slow muon source to attract users to the J-PARC muon facility.

Accelerators:
The remarkable achievement of an effectively 100 kW beam at the beam dump of the RCS is a good omen for early achievement of high power at the neutron beam target - though this will be ultimately limited by the LINAC injection energy. The energy recovery program to full 400-MeV injection is a priority for both the neutron target and the 50 GeV accelerator systems and their experiments. The Accelerator Technical Advisory Committee (A-TAC) of the International Advisory Committee (IAC) has repeatedly recommended that this be undertaken "as soon as possible". The encouraging report on present accelerator performance by Professor Nagamiya indicates that an intermediate threshold power might be obtainable in 2009-2010 with the full conversion achieved by 2011-2012. The A-TAC has recommended that any delay in energy upgrade should allow reconsideration of more advanced technology for the components of the LINAC to add on additional power.

These performances are reckoned to be achievable so long as suitable improvements to the accelerator systems are carried out as well as the energy upgrade as recommended by A-TAC in its 2008 report to IAC.

Targets:
There is no spare target for the neutron experiments and although the initial beam power will not warrant a target change unless there are unforeseen developments, it would be wise to budget for a second target as higher powers become possible towards 750 kW and 1 MW. The retention of good funding for target development in collaboration with the SNS (USA) and the continued sharing of technical advice is most desirable as the two sources move up in a parallel way towards operation at their designed power and power dissipation beyond present experience.

Personnel:
The IAC has recommended that instrument staffing - both scientific and technical - be provided at the level of the best international standard. The instruments at J-PARC will have high throughput and need highly trained staff to ensure this and to cooperate in the training and instrument use of novice national and international users from academia and industry. The success of this interface cannot be overstressed as the vital component at this stage in the J-PARC operation phase.

KEK's role in enabling important science and technology relevant to economic, energy, health:

KEK has the opportunity to be among the world's leading institutions which enable and carry out forefront and pioneering research across a range of materials, life, chemical, environmental and applied sciences. A central component of this vision comes through providing, and further developing, world class accelerator-based facilities and instruments that serve KEK researchers, the Japanese academic and industrial research communities, and a broader Asian and worldwide community. KEK should pursue a future strategy that combines innovative R&D, construction and operation of major photon science, neutron and muon facilities with cross-cutting Centers of Excellence driven by compelling grand challenge science questions. A global outcome of this endeavor will be a dramatically increased understanding of basic structural and functional properties of materials and how they can be tailored and controlled on the nano and atomic scale. Such research will contribute strongly to solving important societal challenges facing Japan and the world. Examples include:

- Design of new, highly selective drugs to manage and cure human diseases, thus improving the health and well being of the Japanese population

- Achieving a better understanding of man-made and natural environmental pollution and enabling science-based strategies for efficient and cost effective remediation processes

- Design and deployment of improved chemical and materials-based processes for delivery of clean, efficient, sustainable and environmentally friendly energy production, transmission, storage and conversion.

Such advances will return direct and tangible benefits over the longer term to the economic and energy security of the Japan.

- **Future Accelerator Plans:**

In order to address the full breadth of accelerator based science, expertise in synchrotrons, storage rings and linear accelerators and the theoretical underpinnings of each is required. The subsidiary technologies involved include the full array of accelerator components using both normal conducting and superconducting materials and devices. KEK is the only laboratory in Japan that has expertise in all of these areas as well as the instrumentation to go with them.

This expertise puts KEK in an excellent position to make scientific advances at the frontiers of the accelerator based sciences. J-PARC and KEK-B benefit from the long experience in synchrotrons, storage rings and their components. ILC and LHC benefit from the strong accelerator physics expertise as well as superconductivity technology of magnets and radiofrequency cavities while the ERL benefits from expertise in x-ray science and technology as well as synergy with the ILC activities.

The future accelerator plan builds on the remarkable history of accelerator success at KEK. Each of the major frontiers of accelerator based science is being engaged by the KEK Roadmap. J-PARC and KEK-B address the intensity frontier, ILC and LHC address the energy frontier and the ERL addresses the frontier of photon science. We find that this is proper and necessary because KEK is the only broad-based accelerator laboratory in Japan. It is to be noted that to match the expansion of the accelerator based sciences requires that attention to enhancing accelerator capabilities be given. This includes training of young people and developing leadership for design, commissioning and operation of accelerators and beamlines as well as improved integration of the existing accelerator expertise to take advantage of the natural synergies. In addition it will be important to recruit international collaborators to supplement the current staff should all of the elements of the Roadmap come to pass or the timing result in manpower resource conflicts.

- **R&D for the innovative particle detectors:**

The KEK management initiated the Detector Technology Project to coordinate common R&D activities for various experiments, to enhance active interactions among detector developers, and to develop innovative particle detectors for future experiments.

The common R&D topics are SOI (Silicon-On-Insulator) Pixel technology, new photon sensors, 2D gas detector, and ASIC. This R&D effort has been applied to experiments such as Belle, ATLAS, T2K, and ILC experiments. The experiments also share expertise of DAQ, computing and cryogenics. This new initiative is seen to be very successful so far.

The next mission of the project is to apply these developments to fields beyond particle physics and nuclear physics. The effort has already started. To name a few, GEM for a neutron detector, SOI for an X-ray detector, PPD for PET (Positron Emission Tomography), Liquid Xenon TPC for PET, 4D detector by combining TPC, GEM and Pixels, and superconducting Tunneling Junction device for Astro-particle physics.

The project has also been successful in recruiting non-KEK scientists to this generic detector development effort. This is an excellent example of KEK playing an important role in supporting the scientific community.

The Roadmap Review Committee concludes that this is an excellent detector R&D strategy.

Charge 3: Assess if the goals of the proposed programs are realistic and achievable in the given time frame by given human resources and budgetary constraints and also if they are attractive to the international community:

The scientific themes of the roadmap present an excellent and challenging but, given the experience and dedication of the staff of KEK, feasible program. The program comprises forefront projects in the areas of photon science, nuclear and particle physics. It also comprises in-house and off-site projects well balanced to keep the already well established international role of KEK in these areas. The unanimous conclusion of the Committee is that the basic parts of the goals of the projects as outlined for the next five years can be achieved within the budget presented by the directorate of KEK. It is, however, obvious that the international standing of KEK demands a more ambitious schedule and, consequently, stronger efforts in most areas. This applies to all three areas mentioned above but in particular to the high priority projects which are the upgrade of KEK-B, the ILC efforts and the ERL project, in order of priority as pointed out to the Committee by the KEK management. The human resources are available at KEK, with excellent expertise, in some cases even unique in the world and need to be adequately supplemented by additional funding. The foundations for the best usage of these resources have already been laid, either through the existing facilities in use or by the preparations for test facilities and novel projects. It is now of high importance for the management of KEK to continue to build on these foundations and to this end it is very important to increase the funding for these projects beyond the absolute minimum which the budget represents at this moment. Again, this represents the unanimous opinion of the Committee.

Charge 4: Evaluate the physics program at J-PARC, particularly in conjunction with its similarity to the one at Project-X at FNAL and other competitive programs.

This type of decision must be made at the grass-roots level. A joint workshop supported by laboratories involved should be the beginning of the process. It can begin with collaborative R&D activities among the competing institutions. The decision on how to bring the plan to reality, deciding whether one proposal should be carried out, both proposals should be carried out competitively, or a joint project should be promoted, must be done on a scientific basis and with the initiative of scientists involved. This will give better opportunity for collaborative endeavors, and even when the situation becomes competitive, it will foster more productive cooperative competition.

Charge 5: Give general opinions on the roles that KEK is anticipated to play in the long range global scope of accelerator based science in the future:

The future accelerator plan builds on the remarkable history of accelerator success at KEK. Each of the major frontiers of accelerator based science is being engaged by the KEK Roadmap. J-PARC and KEK-B address the intensity frontier, ILC and LHC address the energy frontier and the ERL addresses the frontier of photon science. We find that this is proper and necessary because KEK is the only broad-based accelerator laboratory in Japan. It is to be noted that to match the expansion of the accelerator based sciences requires that attention to enhancing accelerator capabilities be given. This includes training of young people and developing leadership for design, commissioning and operation of accelerators and beamlines as well as improved integration of the existing accelerator expertise to take advantage of the natural synergies. In addition it will be important to recruit international collaborators to supplement the current staff should all of the elements of the Roadmap come to pass or the timing result in manpower resource conflicts.