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19 April 2002

Professor S Nagamiya
Director Joint Project of JAERI-KEK
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JAPAN

Report of the International Advisory Committee on the Joint Project April 2002

Dear Professor Nagamiya,

I ***enclose*** the formal report from the International Advisory Committee which met in Tokyo from 6-8 March 2002. On behalf of the Committee I would like to thank you and all of your colleagues in JAERI-KEK for their most helpful presentations and subsequent interactions with Committee as the report was finalised. Your own help has been invaluable to us.

The Committee was greatly impressed by the scope and potential of the project. It is of such importance to Japan and the world that we believe that a policy of “world-class standard’ should be adopted. From day one of the facilities operation, the most novel aspects of the programme should attract the world’s attention and involvement from the importance of the results produced.

This priority was utmost in our mind but it engenders the need by yourself as Director to set priorities within the defined resources of the project. The project makes suggestions about these and about processes. My impression of the Committee’s suggestions is that high priority must be given to neutrinos and neutrons (with 10 instruments), a selection of the exciting experiments on Rare Decay and a selection of the experiments involving Hypernuclei.

The Committee has spent some time in correspondence with one another in order to clarify as far as possible, the important process of prioritisation. An important aspect is the degree of international collaboration that can be attracted at the earliest possible stage in the conception of experiments and the design of the facility. We draw attention to the recommendations in this regard.

Yours sincerely

Professor J W White
Chairman of the International Advisory Committee

THE INTERNATIONAL ADVISORY COMMITTEE

ON THE JAERI-KEK JOINT PROJECT

REPORT

Meeting March 4-6 2002

Tokyo, Japan

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EXECUTIVE SUMMARY

The International Advisory Committee to the Director of the Japanese Atomic Energy Research Institute (JAERI) - High Energy Accelerator Research Organisation (KEK) joint project (JAERI-KEK Joint Project) met on March 5-6, 2002 in Tokyo and Tokai.
This project combines KEK's Japan Hadron Facility (JHF) and JAERI's Neutron Science Project (NSP) into one major facility- the Joint Projectto be built at JAERI's Tokai site by the two partners. The members of the Committee were:

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The "Charges" to the Committee were

- to advise if the project is progressing in a proper way in terms of budget, organisation, schedule, technical development including accelerator technologies etc
- to advise on scientific priorities, in particular on Phase 1 sciences and the Phase 2 sciences

These questions are addressed throughout this report and summarised in the Recommendations. In connection with the second of these charges we have examined the science proposed so as to offer some advice about choices that might have to be made.

With more than 300 people from KEK and JAERI now working on the project the Committee was pleased to see that the joint project has made a strong start towards realising its objectives. Signing of the memorandum of understanding between KEK and JAERI in May 2001 was a milestone marking the start of construction subsequent to the Japanese Government's agreement on 1,335 Oku Yen over six years for Phase I. (This is 133.5 billion Yen). A total budget of 1,890 Oku Yen for Phase I and Phase 2 is forseen. The project covers a wide range of scientific frontiers of the 21st century and will be a world-class research establishment. Already indications are that it will attract world-class scientists from many communities, including particle and nuclear physics, condensed-matter science, and energy technology.

The Committee advises that with this project Japan has the opportunity to be a world leader in a number of fields. The Committee's meeting was held at an important stage in the project and we recommend some key decisions on structure and process in the next year to allow the team to achieve this end.

While all projects presented looked very interesting to the committee **it is recommended** that given the budgetary, manpower and schedule constraints posed by the splitting of Phase I and Phase II some prioritisation of projects would be necessary in the coming year. The **committee furthermore recommends** a policy of "world class standard" in the quality of the construction of the accelerators and the initial suite of supporting instruments even if the number of instruments or experiments has to be limited. Our advice to the Director is that he ensure that from day one of the facility's operation the most novel aspects of the programme attract the world's attention to and involvement in the project from the importance of the results produced.

The Accelerator System

The JAERI-KEK Joint Project entails the construction of a state-of-the-art proton accelerator complex consisting of a 400 MeV linac, a 3 GeV rapid cycling synchrotron, and a 50 GeV synchrotron. The two synchrotrons are designed to deliver extremely high average power: 1 MW from the 3 GeV accelerator and 0.75 MW from the 50 GeV ring. Performance criteria for the accelerators have been established, advanced conceptual designs are complete, and major procurements have been initiated in a number of areas.

The committee did not engage in a detailed review of the technical design, however two issues were brought to our attention that we believe are deserving of attention by project management:

(a) There appears to be a significant shortfall between the staff size that the accelerator group believes is required to construct the facility and currently assigned people. The **committee recommends** that Project Management should develop a strategy for assuring that sufficient manpower is assigned to the accelerator project to assure successful completion.

(b) While the committee believes that the user community of this facility will carry expectations of a high level of operational reliability, it does not appear to the committee that availability/reliability criteria have been relayed to the accelerator group. The **committee recommends** that availability/reliability criteria be developed and formally communicated to the accelerator design/construction team. IAC agrees with the formation of Accelerator Technical Advisory Committee (TAC) under the IAC.

The Science
Nuclear and Particle Physics

The centerpiece of the nuclear and Particle physics portion of the project is a 50-GeV proton synchrotron along with its ancillary facilities. One of the outstanding questions of the latter part of the 20th century is the origin of mass and in the neutrino sector a recent Japanese result from the Super-Kamiokande detector (SK) has confirmed that neutrino have also a non zero mass. Hence it seems that both in the quark and lepton sector, masses and mixing between mass eigenstates control much of the underlying physics . The values of the neutrino masses and of the mixing parameters between neutrino types is of paramount importance not only for particle physics but also for astrophysics and cosmology.
A pioneering experiment observing the evolution of man-made neutrino between the KEK-PS and the Super-Kamiokande detector is attempting to confirm the results obtained at SK with atmospheric neutrino. The definitive experiment will only be possible with the large neutrino fluxes which could be derived from the Joint Project. A unique world opportunity exists due to the existence of the well understood SK detector and of the highest intensity synchrotron accelerator from which neutrino beams of the appropriate energy can derived and directed toward SK. This experiment will measure key elements of the mixing matrix between neutrino states and show possibly evidence for CP violation in the lepton sector, a key element to explain the asymmetry between matter and antimatter in our universe. Hence **we recommend** that the Super-Kamiokande detector be rebuilt as a matter of urgency to start this program as soon as beam is available from the 50 GeV accelerator. We **further recommend** that ways be studied to bring forward the high power operation of this accelerator and the development of the associated neutrino beamline. Japan is the leader in this field and the committee had evidence of immediate and strong international collaboration for this project.

By 2007, the 50GeV accelerator could produce the highest intensities of charged and neutral K-mesons. This will present a unique opportunity to study key rare decay processes which have a direct (and theoretically clean) interpretation in terms of the mixing matrix of quark states. More specifically it could help determine precisely the contribution of such mixings to the violation of CP symmetry in the context of the Standard Model of particle physics. Now that CP violation effects have been seen in the B-meson system as well, at KEK-B (Belle experiment) and at SLAC (BaBar experiment), a detailed comparison of CP violation effects in the K and B meson systems will shed new insights on the validity of the Standard Model and possibly indicate clues for physics beyond it. Such precise comparison can only be made with kaon fluxes such that tens to hundreds of rare events can be identified (only two events have been found so far for the charge kaon decay into a pion and two neutrinos at the BNL-AGS facility). The high intensity of the Joint Project is crucial for future efforts
With a strong Japanese effort in the current rare K-decay searches at the AGS and at the KEK PS and a leading effort in the study of B-mesons at KEK-B, the Japanese scientific community can

develop a world leading program in this field. The search for physics beyond the Standard Model can also be derived from a program on other kaon decays but also from rare muon decay searches. There is a renewed interest in this sector because several new models based upon supersymmetric grand unified theories predict branching ratios which would be accessible to experiments using very intense muons sources as is envisaged for the PRISM project at the Joint Project or at future neutrino factories.

The Committee was given a survey of the potential program in hypernuclear physics with the slow extracted protons from the 50Gev accelerator. A unique program of spectroscopy of S=-2 nuclei giving information on baryon-baryon interactions in nuclear matter is envisaged. High Precision spectroscopy of hypernuclei could also be part of the initial suite of experiments. A strong case was made that this field is ripe for a renaissance and would trigger a strong interest in the nuclear physics community provided that the right facilities are made available. The very high intensity to be available at the Joint Project will allow construction of high quality secondary beams: the hyper nuclear program would most benefit from very pure kaon beams (using doubly separated beams) and from well focused microbeams. With the existing suite of instruments already developed for the KEK-PS program (Hyperball, SKS spectrometer, CDS) or obtained from other laboratories (SPES spectrometers from Saclay), a world class facility hypernuclear physics would become available which would attract also a large international community. It is **recommended** that a careful prioritizing of the initial physics objectives be undertaken by the relevant physics advisory committee with the view of influencing at an early stage the decisions which have to be made regarding the secondary beamlines and experimental facilities.

Material and Life Science Experimental Facility

The centerpiece of the material and life science facility is the spallation neutron source (JSNS) associated with neutron scattering facilities and the muon science facility providing muon beams of highest luminosities. These facilities which are driven by the one megawatt proton beam will produce intense fluxes of neutrons and muons, respectively, to be used for condensed matter physics, chemistry, structural biology, materials science, technology research, fundamental neutron and muon physics and other applications.
The Committee **recommends** that very high priority be attached to the construction of these 'world class' facilities.

Neutron Science Facility

The new 1MW neutron source will provide opportunities to do cutting-edge science in the 21st century. The facility will have one of the world’s most powerful neutron sources and it will attract key problems from all over the world in the communities of physics, chemistry, materials science, structural biology, industrial science and others. A total number of at most 25 beam lines view several moderators appropriately positioned and an area for the possible construction of the second target station in future is well allocated

We **recommend** that well defined priorities be set by the director during the coming year to allow a broad suite of instruments to be ready as soon as the first beam will be available.

Today some of the most important goals of science are to understand and describe life sciences in terms of physical and chemical processes and to integrate physical and chemical properties into functioning systems at the nano scale. There is a strong scientific community in these areas in Japan and we note its growing interest for technological research and its applications to industry.

We **recommend** that action should be taken to pursue a possible participation in this life science facility by active institutions in this area such as RIKEN to further promote exciting science at this facility.

A megawatt pulsed neutron source is complementary to reactor-based continuous neutron source. Japan has a great opportunity of such complementary use of both the JSNS and the existing JRR-3M reactor located within 1km in the campus of JAERI Tokai Research Establishment if a well integrated users program is formed. The JSNS will also provide a great opportunity to Asian-Pacific countries which have medium-size research reactors such as Australia, China, India, Indonesia, Korea and Taiwan. The JSNS also plays a complementary role to synchrotron x-ray sources in the Asia-Pacific region.

Muon Science Facility.

Intense low energy muon beams will be produced from a 20 mm Carbon target irradiated by the 3 GeV protons. Due to the time structure and intensity of the primary beam, the world strongest pulsed muon source will be created. This opens bright prospects for designing dedicated facilities and experiments of outstanding quality, also attracting the international muon user community. For example, one development pushed independently at RIKEN/RAL and PSI are ultra-low energy (keV) muon beams allowing unprecedented surface studies of materials.

We recommend that proposals, selection and design of such dedicated facilities and/or experiments should now be started by the Japanese experimental (and international) community so that the design of the proton target station does not preclude the optimization of muon facilities.

Nuclear Waste Transmutation.

The Committee notes the potential of this program to develop a Transmutation Experimental Facility (TEF) and demonstrate technologies to deal with problematic long-lived radionuclides in nuclear waste. It thus accords it a high priority. The proposed effort presented by JAERI researchers addresses key questions associated with the use of high-energy particle accelerators and subcritical nuclear systems for nuclear transmutation. We note particularly that the proposed TEF-P facility, comprised of a subcritical nuclear assembly "driven" by a low-power proton beam, would be unique in the world. It would play a principal role to develop in-depth understanding of coupled accelerator-nuclear systems needed for eventual application of this technology pathway to nuclear waste transmutation.

We recommend that JAERI-KEK vigorously pursue international participation and support for the TEF, particularly the TEF-P; some amount of initial design and safety analysis activity for the TEF-P be funded in Phase I of the project.
The International Advisory Committee **recommends** that a proposal be made to the interested countries such as France and the United States to co-ordinate their efforts with Japan and participate in the first demonstration of the ADS technology.

Organisation

The extent to which the vision of the joint project as a free standing International Institute supported by KEK and JAERI can be realised is of key interest to the Committee. This vision foresaw the coming together of different, and in the past only weakly interacting, areas of science and technology, particle and nuclear physics, condensed matter science and the nuclear fuel cycle to give a unique impetus and create cross disciplinary strength for Japan and the neighbouring region. In both the context of the budget implementation and priority setting in the project against budgetary and personel constraints such cooperation would produce the best outcome. We see the organisation structure and the degree of authority given to the Director in the above matters as an important signal to the international community that the vision is real. Much might be lost with the default option of their simply managing a set of competing consortia with their own decision making processes.

There exist very good models of success for managing such a multidisciplinary project at Institute level to avoid duplication, to promote international access and to maximise the attractiveness for national science and technology. One matter of interest to the Committee was the way in which the programmes of the different scientific areas will be orchestrated. We were told of discipline specific PACs in the process of formation. The IAC **recommends** that the director of the facility establish several PACs, one for each machine's scientific program and solicit program and beam priority advice separately from each of these committees. For issues and conflicts among the programs of the individual machines, the director should rely on advice from a high-level, facility-wide policy committee such as the IAC.
The Committee commends the Director for the structure of project committees set up in the last year. These have started to work effectively for the project. Their integration into the management of the science program after start up deserves some thought and we **recommend** that this matter be discussed at the next meeting of the International Advisory Committee along with the development of the scientific user community. Input from the User Consultative Committee would be desirable on this point.

We **recommend** that budgetary delegation be given to the Director subject to half yearly review by the Steering committee. Because of the importance of international collaboration we **recommend** that international collaborative delegation be given to the Director subject to half yearly review by the Steering committee.

Recommendations Summary

THE ACCELERATOR SYSTEM

(1) We **recommend** that Project Management should develop a strategy for assuring that sufficient manpower is assigned to the accelerator project to assure successful completion.

(2) We **recommend** that availability/reliability criteria be developed and formally communicated to the accelerator design/construction team.

THE SCIENCE

Nuclear and Particle Physics

(3) We **recommend** that the Super Kamiokande detector be rebuilt as a matter of urgency to start this program as soon as beam is available from the 50 GeV accelerator.

(4) We **recommend** that ways be studied to bring forward the high power operation of this accelerator and the development of the associated neutrino beamline.

(5) Because of strong effort in current rare K-decay searches, the Japanese scientific community can develop a world leading program in this field. The committee endorsed the science objectives as world class with the **recommendation** that priorities be set and international collaboration be encouraged to maximize the cost-benefit ratio of the rather expensive investments which are required for such searches.

(6) The hypernuclear program would most benefit from the very high intensity available at the Joint Project with the existing suite of instruments already developed or possibly obtained from other laboratories. It is **recommended** that a careful prioritizing of the initial physics objectives be undertaken.

Material and Life Science Experimental Facility

(7) The centerpiece of the material and life science facility is the neutron spallation source associated with neutron scattering facilities. **We recommend** that very high priority be attached to the world class' construction of these facilities. The associated muon facilities will give a great improvement in intensity over the current KEK facility and will be outstanding after realisation of Phase II.

(8) We believe that it is most important to stimulate participation in this life science facility by active institutions in this area such as RIKEN to define a strong life science research program

(9) We understand that funds will have to be found and priorities set to allow a critical suite of new instruments to be available on day one. We **recommend** that the Director develop ways of doing this, in the budgetary context, during the coming year.

(10) We **recommend** that proposals, selection and design of dedicated muon facilities and/or experiments should now be started by the Japanese and international experimental community. The design of the proton target station should not preclude the optimization of muon facilities.

Nuclear Waste Transmutation.

(11) We believe that Japan has a unique opportunity to play a major role in the demonstration of nuclear waste transmutation with accelerator driven systems. We encourage JAERI and KEK to further develop their contacts with foreign research organizations and obtain their participation and support for the TEF, particularly the TEF-P. We believe that given the concern of Japanese citizens it is of strategical importance that an initial design and safety analysis activity for the TEF-P be funded in Phase I of the project.

BUDGET AND ORGANISATION

(12) We believe that given the budgetary, manpower and schedule constraints posed by the splitting of Phase I and Phase II a clear prioritization of projects is necessary in the coming year.

(13) We **recommend** a policy of "world class standard" in the quality of the construction of the accelerators and the initial suite of supporting instruments even if the number of instruments or experiments has to be limited.

(14) We believe that the different workshops organized to discuss international collaboration around this project have already attracted the world attention. It is at the scientific and technical level that Japan has the best chances of success in attracting international support. We **recommend** that attraction of international collaboration be one of the priorities of the director.

(15) We **recommend** that the director of the facility establish several PACs, one for each machine’s scientific program, and solicit program and beam priority advice separately from each of these committees. For issues and conflicts among the programs of the individual machines, the director should rely on advice from a high-level, facility-wide policy committee such as the IAC.

(16) The Committee commends the Director for the structure of project committees set up in the last year. These have started to work effectively. Their integration into the management of the science program after start up deserves some thought. We **recommend** that this matter be discussed at the next meeting of the International Advisory Committee along with the development of the scientific user community. Input from the User Consultative Committee would be desirable on this point.

(17) We **recommend** that budgetary delegation be given to the Director subject to half yearly review by the Steering committee.

(18) Because of the importance of international collaboration we **recommend** that international collaborative delegation be given to the Director subject to half yearly review by the Steering committee.

GENERAL REPORT

INTRODUCTION

The Committee listened to presentations from both institutions for a day and a half on March 5-6, 2002. There was a half-day of executive session on March 5 and subsequently a visit to the facilities at Tokai.

The Committee expresses its appreciation to Mr. Ken-Ichi Murakami, President of JAERI, and Professor Hirotaka Sugawara, Director General of KEK for their support of the review process and to the Project Director Professor Shoji Nagamiya, Director Dr. Hideaki Yokomizo and Joint Project staff for their hospitality.

The Advisory Committee noted the report of the International Review Committee of the Joint Proposal of the Japan Hadron Facility (KEK) and The Neutron Science Project (JAERI) April 26-28, 1999 and in particular the "Points of Review" set then to analyse the project.

Overview of the Facility

The proposal combines one plan to build a purely academic research facility and another plan to build a nuclear science and technology oriented facility into one project.

Phase 1 of the proposed combined facility to be built at the Tokai site consists of:

- 400-MeV linac system
- 3-GeV synchrotron operating at 25 Hz and delivering 0.33-mA average beam current (3-GeV, 0.33-mA provides 1-MW of beam power)
- Muon experimental area
- Neutron source and neutron scattering area
- 40-GeV synchrotron delivering 15-mA average current with slow extraction.
- K-meson experimental area

Phase 2 of the project will be:
- Neutrino experimental facility
- Upgrade of the accelerator to 50 GeV with fast extraction for neutrino experiments.
- An additional 200-MeV superconducting linac to make a 600-MeV linac system for a transmutation experiment
- Transmutation experimental area

Phase 2 of the project will be to upgrade the accelerator to 50 GeV with fast extraction for neutrino experiments.
The Advisory committee was grateful for additional comments from the presenters on the science project and the accelerator construction. These and the presentation allowed the committee to appraise the science and technology case and to assess the developments that have been made since the 1999 report and especially since the project officially

began in April 2001. The committee's appraisal is summarised below under the following headings:

SCIENCE AND TECHNOLOGY

Accelerators

The JAERI-KEK Joint Project entails the construction of a state-of-the-art proton accelerator complex consisting of a 400 MeV linac, a 3 GeV rapid cycling synchrotron, and a 50 GeV synchrotron. The two synchrotrons are designed to deliver extremely high average power: 1 MW from the 3 GeV accelerator and 0.75 MW from the 50 GeV ring. These capabilities are beyond those of any other accelerators operating elsewhere in the world today.

Performance criteria for the accelerators have been established and advanced conceptual designs are complete. Full scale prototypes of most critical components are either completed or in progress. Procurements have been initiated, most notably for the drift tube linac and dipole, quadrupole, and sextupole magnets for the 50 GeV ring.

Because this facility is pushing beyond current state-of-the-art there are a wide range of technical challenges in achieving performance goals. Most of these challenges are directly related to the very high average beam power delivered from the complex. While this committee did not engage in a detailed review of the technical issues—this will be handled by the currently forming Technical Advisory Committee—a number of issues were brought out in our meeting that we believe are deserving of attention by the project management:

- Human Resources

  The Accelerator Group Leader stated that a staff of approximately 200 people was required to construct the accelerator facility. At the moment approximately 100 people are available. The strategy for closing this gap, as required for a successful project, was not evident to the committee. The **committee recommends** that Project Management should develop a strategy for assuring that sufficient manpower is assigned to the accelerator project to assure successful completion. In developing such a strategy management may wish to consider the size of the staff that will be required to support the accelerator facility during its operational phase as well as the opportunities presented to train new people in the technologies of accelerators.

- Availability Criteria

  The committee believes that the users of this facility will expect an extremely reliable operation, approaching 95% defined as actual/scheduled operational time. However, it does not appear that availability/reliability criteria have been relayed to the accelerator group nor are formally reflected in their planning. The **committee recommends** that availability/reliability criteria be developed and formally communicated to the accelerator team.

· Beam loss criteria and machine protection requirements

Beam loss criteria have been developed for the accelerator complex. The criteria are ambitious, but also necessary to allow sustained operations at the established performance goals. Diligence must continue throughout the design and construction stages to assure that these criteria can be met. In particular, single pulse accidents need to be investigated somewhat more thoroughly than they have been to date.

· Readiness for Component Procurement

The committee notes that major procurements have been initiated based on technical design reviews conducted by a variety of committees over the last several years. While to all appearances the design of the accelerator complex appears sound, the committee did not undertake a review of the accelerator design at a level of detail to allow us to determine that the initiation of major procurements is appropriate at this time. The committee recommends that the Technical Advisory Committee currently being formed be asked to look at readiness for procurement as part of their charge.

Finally, the committee notes that many institutions in Europe, North America, and Asia are contemplating projects that contain considerable overlap with the technologies being developed for the Joint Project. As such opportunities for collaboration on the accelerator project with institutions outside of Japan exist and should be encouraged.

PARTICLE AND NUCLEAR PHYSICS

By producing an unprecedented flux of high-energy protons, the Joint Project will provide a unique hadron facility for the world physics community. The 50-GeV 15-μA objective will be realized in a realistic time frame. Further intensity gain will be possible in the future.

The proposal describes the wide range of particle physics issues which will be addressed by the new facility with its secondary K, μ, ν and $\bar{p}$ beams. Selection of the most pressing topics will be required to focus the program on the most relevant questions.

In the presentations the Committee was given the current thinking of the Joint Project proponents regarding the initial key experiments they planned to develop. The choice was motivated by physics interest and the ability of the facility to expand the experimental reach into new frontiers. The Committee agrees that the three main areas, neutrino oscillations (of relevance to neutrino masses and mixings), rare K decays (of relevance to CP violation), and lepton flavor-violating decays (of relevance to lepton mixing), represent the most exciting opportunities for the 50-GeV program.

The Committee recognizes that the 50-GeV ring presents exciting opportunities for the world nuclear-physics community. The Committee strongly supports in particular the hypernuclear physics, where Japanese physicists are world experts.

Neutrino Physics

In neutrino physics, The Super-Kamiokande (SK) group has recently provided the most credible evidence of $\nu_\mu \rightarrow \nu_\tau$ neutrino oscillations as seen in the measurement of "atmospheric" neutrino fluxes in the SK detector. K2K is the first long baseline neutrino oscillation experiment being carried out in Japan by sending a muon neutrino beam produced at the KEK P.S. to the SK detector (250 km baseline). Recent results from K2K are confirming the oscillation of atmospheric neutrinos. Precise observations of solar neutrinos by SK and SNO provided firm evidence for $\nu_e \rightarrow \nu_{\mu,\tau}$ oscillations as the solution of the long-standing solar neutrino problem.

With its much higher energy and beam intensity, the Joint Project will allow a precise determination of the underlying parameters for the $\nu_\mu \rightarrow \nu_\tau$ oscillations, detailed study of the third and last oscillation mode $\nu_\mu \rightarrow \nu_e$, and study of the CP violation in the neutrino sector. The 50-GeV proton beam with fast extraction is necessary to produce the intense muon-neutrino beam with neutrino energies optimized to the oscillation maximum. The high intensity is needed to gain high enough statistics and appearance of electron-neutrinos. The muon-neutrino beam is directed to the SK detector and in the future to Hyper-Kamiokande.

Two experiments are expected to start data taking in 2005 in the US (FNAL – Soudan, 730 km baseline) and Europe (CERN – Gran Sasso, 730 km baseline) for studying the $\nu_\mu \rightarrow \nu_\tau$ oscillations. Though the Joint Project neutrino experiment will start 2 years later than the US and European counterparts, it will provide better as well as new and complementary results thanks to the high intensity neutrino beam with the optimized neutrino energies

Rare Kaon Decays

Amongst the Kaon decays to be studied, the measurements of the $K^+ \rightarrow \pi^+\nu\bar{\nu}$ and $K° \rightarrow \pi°\nu\bar{\nu}$ (direct CP violation mode) branching ratios are the most attractive because a 10% determination of these branching ratios determines with similar precision the two elements of the quark mixing matrix, $|V_{td}|$ and Im $(V^*_{ts}V_{td})$, respectively, the latter controlling CP violation effects in the Standard Model (S.M.). The expected branching ratios are ~9 x 10^{-11} and ~3 x 10^{-11} for $K^+ \rightarrow \pi^+\nu\bar{\nu}$ and $K° \rightarrow \pi°\nu\bar{\nu}$, respectively. With the major effort being expended at present on the B meson system, one will be able to subject the S.M. to a detailed test and any inconsistency between the determination of the mixing parameters in the B and the K systems will point to specific extension of the S.M. For example the minimal-supersymmetric-model (MSSM) extension of the S.M. would shift the prediction by 10 – 20 % for Kaon decays but no change for B meson decays.

Experiments foreseen at the 50 GeV ring will be able to accumulate a few 100 and about 100 events in a year for $K° \rightarrow \pi° \nu \bar{\nu}$ and $K^+ \rightarrow \pi^+ \nu \bar{\nu}$ decay modes, respectively.

Currently the charged decay mode is being studied at the AGS, E949 experiment, which expects 5 – 10 events in two years.

The program at Fermilab on $K^+ \rightarrow \pi^+ \nu \bar{\nu}$, the CKM experiment, has been approved and plans to start data taking in 2007. It will be able to accumulate 100 events. So far no experiments have found evidence for the neutral Kaon decay $K° \rightarrow \pi° \nu \bar{\nu}$. The KOPIO experiment at the AGS is expected to run in 2007 and obtain 50 events in three years.

Japanese physicists and more specifically young Japanese researchers are involved in the present world effort on rare K decays and often lead the current effort. They are the prime potential leaders of the future Joint Project effort.

Lepton Flavor Violation

The third main line of research to be developed at the Joint Project will be the search for lepton flavor violation (LFV) processes ($\mu \rightarrow e\gamma$, $\mu \rightarrow eee$, $\mu^- N \rightarrow e^- N$ or $\mu^+ e^- \rightarrow \mu^- e^+$) with a new high acceptance muon source. Of these processes, μ-e conversion ($\mu^- N \rightarrow e^- N$) has the highest potential for large improvement at a low-duty-cycle high-intensity accelerator, because it does not suffer from background of accidental coincidences as do other processes. There are two new developments in this field which make this research timely:

Theoretically, the Supersymmetric Grand Unified theories (SUSY GUT) predict that LFV will occur with branching ratios within reach of experiment at a high flux facility and, experimentally, the recent proposal to develop very high acceptance muon sources with phase rotation cooling which will provide several orders of magnitude improvement in muon fluxes.

This makes the Joint Project experimental program in lepton flavor violation experiments extremely timely and the most likely place to test these ideas. Already a very active working group is preparing test experiments on the super muon channel technology and experiments have been proposed by Japanese groupsat PSI and TRIUMF along these lines.

A competing effort called MECO has been proposed for the AGS program and if funded will pave the way towards the sensitivities of the branching ratio down to 10^{-16}.

The Joint Project capabilities will be required to reach SUSY GUT predictions. The PRISM collaboration proposes a high-intensity, monochromatic muon source by means of a phase rotation technique using a FFAG synchrotron. A muon yield of 10^{12} /s is expected. A mu-e conversion experiment with PRISM could reach the sensitivity level of

10E-18. PRISM could be an injector of a neutrino factory and a muon collider in the future. The fast extraction scheme of the 50 GeV ring is required as for the neutrino beam.

In conclusion, the Joint Project experimental program will build upon a unique capability in terms of secondary beam fluxes and a base of expertise, which exists at KEK and in Japanese universities.

Beyond the three lines of research cited above, other opportunities will exist with antiproton beams (it is proposed to re-establish the low-energy antiproton ring which has been obtained from CERN) and with polarized protons. Also possible will be further upgrades in intensities and duty cycle when the injector system is fully operational.

The Joint Project will be the world hadron facility that the community has demanded to push its experimental reach to the frontier of neutrino masses and mixings and precision physics (rare decays).

Hypernuclear Spectroscopy

High-resolution (a few keV) and large-acceptance experiments with the Hyper-Ball γ detector will open a new research domain in the spectroscopy of Λ-hypernuclei (S=-1). The data will probe new many-body effects in nuclear matter due to the implantation of Λ in nuclei. Light hypernuclei such as ${}^{4}_{\Lambda}He$ and ${}^{7}_{\Lambda}Li$ have been studied and information on ΛN spin-dependent interactions was obtained. The intense Kaon beam will enable to investigate heavier hypernuclei by (K^-, π) reactions. Japanese physicists have been the pioneers in this domain and their expertise is recognized worldwide.

Λ-hypernuclear spectroscopy will be studied at TJLab in the US by (e,e'K^+) reactions and at FINUDA in Italy by stopped (K^-, π) reactions. Both experiments are expected to run in a few years.

The study of the (K^-, K^+) reactions with a high-resolution spectrometer will provide a way to study the possible existence of S=-2 hypernuclei, such as Ξ- and $\Lambda\Lambda$-hypernuclei or H dibaryon. This will open an important field of research. Experiments could start from day one by bringing the existing SKS spectrometer at KEK.

The Joint Project hypernucleus program should concentrate on high resolution spectropy on S=-1 and S=-2 systems and, as the 50 GeV beam intensity goes up, on heavier hypernuclei. Weak decays of hypernuclei can give important information on hadronic effects on weak interaction such as ΔI =1/2 enhancement and the role of chiral symmetry.

Hyperon-nucleon scattering

The Λ-p, Σ-p and Ξ-p interactions will be studied for the first time in details with the 50-GeV facility. These studies will provide an essential building block for hypernuclear physics. In particular the knowledge of the spin-dependence of the Λ –N interaction and the isospin dependence of the Σ-N interaction will have an impact on understanding QCD in the non-perturbative regime. Other topics of interest are the possible existence of H dibaryon and S = -3 dibaryons that are still open questions.

Vector-mesons in the nuclear medium

The availability of a 50-GeV facility will provide optimum flexibility for experimental studies of the properties of the ω, φ,and *J*/ψ mesons in nuclear matter. One expects in particular that their masses are changed in the nuclear medium. The Joint Project will be the only facility where a clean and definitive answer to the mass generation mechanism for hadrons can be found. The Joint Project will be a unique facility to observe the changes of vector meson properties as a function of nuclear density up to five to ten times the normal nuclear matter density.

Hadron spectroscopy

Glueballs and hybrids are fundamental tests of QCD. Although, their existence has been predicted by many models, the existing data remain inconclusive. Recent experimental results from CERN at the LEAR facility have shown the importance of high statistics in this search. Unfortunately this program at CERN has been interrupted by the shutdown of LEAR. The SUPER LEAR facility will not be built in the future since CERN concentrates its investments on the Large Hadron Collider. Thus, the K^-, π, and antiprotons beams from the 50 GeV ring would be a unique opportunity to study the charmed baryons and mesons, or hybrid states. Such a program would be a remarkable complement to the ones carried out at DAΦNE, Jefferson Lab and SPring-8.

MATERIAL AND LIFE SCIENCES

Neutron Scattering

Neutron scattering provides information at a microscopic level on the structure and dynamics of condensed matter in fields as diverse as Physics, Chemistry, Biology, Materials Science, Earth Science and Engineering. The unique properties of neutrons as a scattering probe, selectivity through isotopic labelling, the magnetic interaction, the ability to probe atomic motion, and the penetrability of the probe, are well established and are responsible for its broad exploitation.

Research with neutrons impacts on a wide variety of topics at the forefront of condensed matter science. Recent examples include the determination of the high resolution structure of high temperature superconductors and fullerenes; the study of excitations in highly correlated electron systems and quantum fluids; the behaviour of complex fluids (surfactants, polymers and proteins) at interfaces; high pressure studies of crystalline materials; and the structure of super-critical fluids. In addition, significant contributions have been made to our understanding at a microscopic level of technologically relevant materials, such as polymers, plastics, proteins, liquid crystals, magnetic materials and superconductors.

Unlike the case for fundamental physics, there is no single experiment or classes of experiment which uniquely make the case for the facility. In contrast, the facility will deliver a capability to understand - and hence influence - the world around us on the angstrom to micron scale. Although unique in its insight, neutron scattering is often complemented by studies with other probes: synchrotron radiation, electron microscopy as well as theoretical studies and computer modeling.

In recent years, Japanese academic and industrial scientists have developed outstanding capabilities in material and life sciences. To date, a pioneering number of these have benefited from access to neutron scattering capabilities at JAERI and KENS, as well as gaining access to world-leading facilities in Europe and America. However the potential impact of marrying world-leading Japanese capabilities in these areas to a world-class facility in Japan is immense. The explosion in the use of synchrotron radiation by a broad community following the development of SPring-8 will certainly be repeated with neutron scattering. Areas where significant advances can be anticipated include:

Soft Condensed Matter
Polymers
Macromolecules
Surfactants
Self assembling systems

Surfaces and Interfaces
bio membrane function
chemical reactions
catalysis
lubrication and adhesion
coating wetting etc

Biomolecular Systems
hydration in proteins
protein dynamics and folding
molecular recognition
pharmaceuticals

Advanced Materials
- Structure function relationships
- Relaxor ferroelectrics/ceramics

Solid State Quantum Systems
High Tc superconductivity
Colossal magnetoresistance
Spintronics
Quantum critical phenomena

High Pressure High Temperature Science
phase transitions in mantel minerals
understanding earthquakes and vulcanism

Industrial Applications
non destructive investigations

The promotion of the industrial applications will be a particular feature of the new source. The current number of users of neutron facilities in Japan is of order 500, but the potential academic and industrial community including users from the Asia-Pacific region could be as much as an order of magnitude greater.

Japan and the Asia - Pacific region will lack the high flux facilities of Europe and the USA by the time that the joint project comes ' on stream' in 2006 and so a strategic opportunity exists to make a world quality impact. The new 1MW neutron source will provide opportunities to do cutting-edge science in the 21st century. The facility will have one of the world's most powerful neutron sources and it will attract key problems from all over the world in the communities of physics, chemistry, materials science, structural biology, industrial science and others. A total number of at most 25 beam lines view several moderators appropriately positioned and an area for the possible construction of the second target station in future is well allocated.

Japanese neutron scientists, through their experience gained in operating and developing the highly efficient KENS source, and through their long-standing collaborations in developing instrumentation at ISIS have outstanding capabilities to develop the next generation of instrumentation needed to exploit fully the potential of the new source. Their involvement of the existing and potential user community in developing a 'straw man' suite of 25 instruments is to be commended. Refinement of these instrument concepts is ongoing, and the need for R&D programmes to develop key components is well recognised. It is imperative that the funds are found and priorities set to allow a diverse suite of new instruments to be available on day one. A day-one target of ten fully optimised operational instruments should be incorporated into Phase I of the project.

The 21st century will be the century in which biology becomes understood in chemical and physical terms and one where the new science will be concerned with integration of physical and chemical properties into functioning systems at the nano and micron scales. We note the strong scientific and growing industrially orientated community in these areas in Japan. However action should be taken to pursue a possible participation in this life science facility by RIKEN currently conducting a large life science program to further promote exciting science at this facility.

A megawatt pulsed neutron source is complementary to reactor-based continuous neutron source. Japan has a great opportunity of such complementary use of both the JSNS and the existing JRR-3M reactor located within 1km in the campus of JAERI Tokai Research Establishment if a well-integrated users program is formed. The JSNS will also provide a great opportunity to Asian-Pacific countries which have medium-size research reactors such as Australia, China, India, Indonesia, Korea and Taiwan. The JSNS also plays a complementary role to synchrotron x-ray sources such as Photon Factory and SPring-8 in Japan as well as many synchrotron radiation sources in the Asia-Pacific region.

Muon Condensed Matter Science

The Muon Science Facility utilising the one megawatt 3GeV proton beam will produce large fluxes of low energy muons of prime quality competitive with present world standards. The muon beams will achieve highest peak luminosities and intensities worldwide allowing the design of outstanding experiments and facilities, especially where the pulsed muon beam technique can be applied.

The new facility will be designed to allow frontier experiments with stopped muons in materials science (solid state physics) employing the Muon Spin Resonance (muSR) method, but as well in fundamental muon physics, e.g. in studies of properties and decays of muons and of muonic atomic and molecular systems.

A typical example where the Muon Science Facility may play a leading role on the world scale is the creation of ultra slow muon beams using the pulsed laser technique which is presently being developed by a RIKEN group. With this technique - given the future high luminosity of "surface" mu+ (muons produced by pion decay on the surface of the proton target) - mu+ beams in the eV to keV range can do unprecedented surface studies of materials on the micron scale.

Japan has already a long tradition in these research fields and is heavily engaged in leading experimental programmes at the superconducting muon channel of TRIUMF, at the RIKEN-RAL facility at ISIS and at the Meson Science Laboratory (MSL) of KEK. The Japaneese researchers, and especially the RIKEN Lab, possess therefore all the knowhow to properly design a 'world class' Muon Science Facility. In this respect, IAC strongly recommends that this accumulated Japanese knowhow in Low Energy Muon Physics and Facilities must be mobilized in the near future to help design the new Muon Science Facility.

We recommend that proposals, selection and design of dedicated facilities and/or experiments should now be started by the Japanese experimental (and international) community so that the design of the proton target station does not preclude the optimization of muon facilities.

A preliminary list of possible physics objectives with the Muon Science Facility has been communicated to the IAC as follows:

- Magnetic phase diagram determination
- Quantum diffusion studies
- Low dimensional magnetic systems
- Heavy fermion systems studies
- Frustrated magnetic systems
- Penetration depth measurement for superconductors.
- Muon induced soliton, polaron in polymers and its detection by muons.
- High intensity negative muon beam as the introduction of a muonic (Z-1) impurity.
- Muon catalyzed fusion experiments
- Fundamental Physics such as precise QED measurement

Obviously, this list is incomplete and proposals must be worked out and reviewed by the appropriate PAC before priorities can be issued.

TRANSMUTATION SCIENCE AND TECHNOLOGY

In recent years, the accelerator-driven transmutation of nuclear wastes has emerged as a potentially complementary technology for radioactive waste handling, by transmuting the longest-lived radioactive isotopes into short-lived or stable ones. Developing this new technology has a significant synergy with the spallation neutron source. Europe and the United States have already made significant studies in this domain, but Japan is the first country to propose the construction of an ADS demonstration facility.

A distinguishing feature of ADS is the strong coupling between scientific/technological issues and public policy regarding nuclear power, nuclear waste management, environmental safety, national security, and related concerns in which public opinion also plays a major role. Although, science policy decisions in this area are particularly sensitive and difficult, there is considerable agreement on the short- and medium-term goals of the research. This is in itself remarkable, since the study of ADS is inherently multidisciplinary, involving for the physics community elements of basic and applied research in the following areas:

- the fundamental nuclear physics of transmutation;
- the spallation process for neutron production, including high-power target technology;
- the design and operation of high-intensity, high-reliability accelerators.

The transmutation of selected long-lived constituents of radioactive waste to shorter-lived or stable by products is a research area of interest to a number of international efforts. A promising approach to creation of workable transmutation systems is through the creation of a high-intensity spallation neutron source which then “drives” a subcritical, multiplying nuclear assembly. Such accelerator-driven assemblies would utilize fast spectrum neutrons, since these are more effective (than thermal neutrons) in the fission of higher actinides such as neptunium, americium, and curium.

The presence of large quantities of such actinides (in addition to plutonium) in a nuclear reactor environment presents significant challenges in areas of control and safety, especially for systems where fuels contain little or no uranium. For such reasons accelerator-driven subcritical systems potentially hold advantages over critical reactor systems, since self-sustaining nuclear reactions cannot occur if the accelerator beam is turned off.

The coupling together of an accelerator, a spallation neutron source, and a subcritical nuclear system is in itself not trivial. To achieve sufficient destruction rates for key actinides, subcritical systems must possess several hundred to several thousand megawatts of fission power. Questions of the dynamic behavior, robustness to material feed makeup variations, and feedback and control of such assemblies must be addressed in order to demonstrate the viability of accelerator-driven systems for transmutation applications.

Plans by the JAERI team to design and build a low-beam power, spallation-source driven, multiplying assembly, the TEF-P (Transmutation Experimental Facility – Physics) represent the key first step towards demonstration of accelerator system viability. This facility will allow determination of dynamic behavior of driven subcritical systems and will create the understanding base needed to develop event detection, feedback, and controls systems for such assemblies. By using simulants of transmutation fuels, results from TEF-P operation can provide integral data for reaction rates of higher actinides – information needed to improve microscopic data libraries used in the design of both reactor and accelerator-based transmutation systems. Finally a planned second-stage, complementary facility, the TEF-T, can provide important materials test and performance data through irradiations carried out using high-intensity, 600 MeV proton beams.

The international interest in such transmutation science and technology research is great. Scientists from the US, France, Russia, Sweden, Italy, Spain, Korea, and China are engaged in such activities. Simultaneously, researchers from leading Japanese universities are also studying the basic aspects of accelerator-driven transmutation. The planned facility will be both a Japanese and international resource in this important field related to long-term management of waste from nuclear power generation.

The full potential of international co-operation and co-ordination has not yet been achieved among those countries that are interested in this technology. As research progresses, there is an increasing possibility that important avenues of investigation will remain unexplored, or that unnecessary duplication will occur. To make optimum use of available intellectual and financial resources, it may be necessary to strengthen existing co-operative mechanisms, or to create new ones.

Scientists are willing to contribute to the development of this potential solution to an important problem in many countries. International co-operation and consultations are proven tools for advancing scientific and technological understanding of ADS, and contacts are frequent on the scientist-to-scientist level. Several conferences and workshops have already been held. There are also mechanisms for exchange of experimental results and compilation of data in international bodies such as the OECD Nuclear Energy Agency (NEA) and the UN International Atomic Energy Agency (IAEA). Formal agreements exist among several research institutions in Europe, North America and Asia.

The International Advisory Committee **recommends** that a proposal be made to the interested countries such as France and the United States to co-ordinate their efforts with Japan and participate in the first demonstration of the ADS technology.

ORGANISATION AND MANAGEMENT

During the presentations, several of the speakers referred to “PACs” that would provide advice on the selection of and relative priorities for the experiments to be performed at the Joint Project. After receiving questions from the IAC about the PAC structure, several of the presenters supplied written commentary on their views of how the imagined PACs are expected to function. These views had more coherence than the oral presentations but there still emerged no clear overall program advisory structure across the facility. Noting this ambiguity, the IAC would like to make the following observations relative to the use of Program Advisory Committees (PACs) plus an associated recommendation:
the scientific program of the Joint Project is so broad that a single PAC will not, in practice, have the span of expertise or committee donated time to properly span all proposed scientific activities in the program, even with a possible mitigation of this burden by the use of a supporting array of expert subcommittees; several PACs will be needed;
in practical terms, each of the accelerators will generate beam-use priority issues that a PAC devoted to the program of that specific machine (3 GeV, 50 GeV and SC Linac) will be asked to consider and make program and priority recommendations to the Joint Project director (or an associate director for that program); linkage between the programs and priority conflicts among the Joint Project machines will also exist but will be weaker in practice, so that priority of use at the machine level could be addressed by a facility-wide policy committee (such as the IAC) reporting to the Joint Project director;
because the mission of the facility is aimed at the *beam intensity frontier*, the simultaneous time sharing of primary beam among experiments for a single machine (by beam splitting or time sequencing in successive machine cycles) will not be feasible in general, so the scientific program will generate serious conflicts of priority, even within the program of a given facility (eg., neutrino running vs. rare kaon decays); the chosen PAC structure needs to plan for this circumstance.

With these points in mind, the IAC **recommends** that the director of the facility establish several PACs, one for each machine’s scientific program and solicit program and beam priority advice separately from each of these committees. For issues and conflicts among the programs of the individual machines, the director should rely on advice from a high-level, facility-wide policy committee such as the IAC.

On an associated governance topic, we noted frequent statements to the effect that the Joint Project was intended to be an “international” effort and facility. From the materials that the IAC saw and heard, this admirable intent will require significant conceptual and planning developments by the project management if it is to be implemented and realized in practice.

A typical process to form international collaboration is:
(1) A series of workshops are held and experimental projects are presented.
Workshops must be organized by people in a specific field, say, neutrino, Kaon, etc. A necessary fund can be requested to the ministry, Monkasho, and also to JSPS.
(2) A meeting is announced for the possible grouping. Some of the attendees are assigned to form a core group.
(3) They then try to formulate each group's contributions and to enlarge the group if necessary.
Workshops in all areas of interest to the Joint Project have been held and more are planned. Since the budget and manpower of the Joint Project are really tight, international groups must seek substantial funds not only for building the detector but also for making the targets and beam line magnets etc.
Since it is already due time or even overdue to form international groups, similar concrete actions are urgently needed for other nuclear and particle projects. Otherwise foreign groups may not have time to contact funding agencies and get funded in time.
Beyond these scientific contact and collaborative organization actions, we note that the implementation of a truly international facility also requires several formal steps that need to be taken in the proper sequence:

- the participation among countries (Asian region, Pacific Rim, or the whole world) and the scope of involvement (design and construction of accelerator and beam facilities;
- design and construction of research program experiments, research collaboration in the operation of experiments via international collaborations, or a combination of these scope extents) should be characterized in a *"Mission Statement"* for the project and its scientific program;
- a "*Roadmap*" document should then be developed that shows, in significant detail, how the mission statement is intended to be implemented and evolve in time, with what desired partners and with what government sanctions (agreements between governments, agreements between institutions, informal university collaborations without specific government sanction, or a combination of all of these);
- the Joint Project officers should begin to develop the enabling documents noted in item 2 for signature by government officials, institutional directors and desired collaborating scientific groups that will thereby formalize and begin to implement the desired actions; *Government-to-Government Agreements* and/or *Memoranda of Understanding* with the desired parties have been the usual instruments to formalize the collaborative activities; the process of arriving at these agreements will be time consuming and should be initiated in the near future.

It is possible that this formalization process has already begun and may even be near completion but the IAC was not informed about it. We **recommend** that these actions be initiated if they are not already in progress.

PRIORITISATION

The Director has indicated to the Advisory Committee his sensitivity to the need to set priorities. There are in existence several methods of how to set priorities.

For Phase 1 Project the budget has already been allocated to individual experimental areas. It is intended to form certain scientific committees, the committee for neutrons already in existence being the first. These committees will discuss which of experiments must fly first. For particle/nuclear physics the process of forming this committee is occurring. A strong weight will be attached to the discussions at these committees on priority setting.

The mechanism of how to set priorities for Phase 2 would be to obtain the input from the International Advisory Committee as a very important component. Its comments on scientific priorities will be reported to the Steering Committee (the Committee where representatives from KEK and JAERI meet). This committee will recommend which budget request must be submitted first.

The progress of priority setting will be reported by the Director at the next TAC

INTERNATIONAL COLLABORATION

International collaboration has been mentioned in several places in this report and in the recommendations. The long term success of the project and its benefit to Japan will depend on setting the parameters for this collaboration correctly as soon as possible for the excellent instruments proposed. The ideas for this need to be agreed in Japan at the project, at the Steering committee and at the highest levels of government. The International Advisory Committee offers its help in this regard with a view to a clear statement of these parameters being available at its next meeting.