Report from the 2nd Meeting of the Accelerator Technical Advisory Committee for the Japan Proton Accelerator Research Complex (J-PARC)

March 7-8, 2003
KEK
Tsukuba, Japan

ATAC Members

Present

R. Garoby/CERN
D. Gurd/ORNL
S. Holmes/Fermilab (chair)
A. Noda/Kyoto
T. Roser/BNL
J. Wei/BNL

Absent

K. Bongardt/Juelich
I. Gardner/RAL (deputy chair)
L. Young/LANL

Agenda of the 2nd ATAC Meeting for J-PARC Project (2/25 version)

March 7th (Fri), 2003

8:00 - 8:15	Welcome Address	S. Nagamiya
8:15 - 8:30	Executive Session	
8:30 - 9:10	Overview (30'+10') Progress of Design Status of Construction Linac Energy Recovery Scenario	Y. Yamazaki
9:10 – 9:35	Beam Powers of the RCS and MR in the case of the 181-MeV Linac Operation (15'+10')	S. Machida
9:35 – 10:55	Linac	
9:35	Answer to the 1st ATAC Report (18'+7') Including Vibration and Error Analysis	T. Kato
10:00 - 10:15	*Coffee Break*	
10:15	MEBT Commissioning Result (18'+7')	M. Ikeagami
10:40	Ion Source Development Strategy including Cesium Issue (10'+5')	A. Ueno
10:55 - 14:30	RCS	
10:55	Beam Optics and Dynamics(25'+10') Feasibility Study of FODO Cell Structure Trim-Q and Dynamic Correction Magnets Beam Halo and the Collimator Configuration	K. Yamamoto
11:30	Rapid-Cycling Magnet System (including experimental results on the stranded cables) (18'+7')	N. Tani
11:55 - 13:15	*Lunch*	
13:15	Longitudinal Bucket Manipulation (18'+7')	M. Yamamoto
13:40	New Design of the Injection System (18'+7')	I. Sakai
14:05 - 16:15	MR	
14:05	Study of the Non-Linearity Effect in 50-GeV MR(18'+7')	A. Molodojentsev
14:30	Design of the Opposite Field Septum Magnet(18'+7')	I. Sakai
14:55	Progress of the MA-loaded Cavity System (15'+5')	C. Ohmori
15:15	Fabrication and Field Measurement of the Magnet (15'+5')	M. Muto
15:35 – 15:50	*Coffee Break*	
15:50 – 16:35	Impedance and Instability	
15:50	Impedance Budget (15'+5')	T. Toyama
16:10	Beam Instability Issues (18'+7')	S. Koscielniak
16:35 – 17:00	Accelerator Computer Control (18'+7')	H. Yoshikawa
17:00 - 19:00	Executive Session	

March 8th(Sat), 2003

8:30 - 11:00	Executive Session, Report Write-Up
11:00	ATAC Report to Management (Open to Everybody)
12:00	Move to JAERI with Lunch Boxes
13:30	JAERI Site Tour

EXECUTIVE SUMMARY

The Accelerator Technical Advisory Committee (ATAC) of the Japan Proton Accelerator Research Complex (J-PARC) held its second meeting over the period March 7-8, 2003 at the KEK laboratory in Tsukuba, Japan.

The J-PARC Project was initiated in 2001 as a joint project carried out by KEK and JAERI. When complete the facility will support research into the areas of Neutron Science and Elementary Particle Physics. The Project is approved with a budget of 133.5 billion yen for Phase 1, and a construction schedule leading to completion in 2006. Phase 2 of the project requires an additional 55.5 billion yen in funding and is not yet approved for construction. The committee notes that when complete J-PARC will provide Japan with the preeminent facility for hadron sciences in the world.

The ATAC heard presentations concerned with the technical design and fabrication of the accelerator facilities supporting the J-PARC Project. These presentations were well prepared and informative, as well as being extremely responsive to recommendations from the May 2002 meeting. In addition the committee toured the construction site and observed many prototype components undergoing testing as well as significant civil construction activities underway. The committee did not specifically review the cost of the facility nor the construction, installation, and commissioning schedule. Presentations and committee discussion concentrated on the Phase 1 project. The committee was very impressed at the degree of progress since the last meeting and congratulates the project team on its very excellent progress in further developing the design and initiating construction of the accelerator complex.

General Comments

When completed J-PARC will be a state-of-the-art proton accelerator complex with associated experimental facilities. The accelerator facility, which was the subject of this review, consists of a 400 MeV linac, a 3 GeV rapid cycling synchrotron, and a 50 GeV synchrotron. The two synchrotrons are designed to provide **extremely high average beam power: 1 MW from the 3 GeV ring and 0.75 MW from the 50 GeV ring**. This performance is beyond that of any other facility operational in the world today. Notable pieces of the project that are currently delayed into Phase 2 include an additional 200 MeV of superconducting linac and associated waste transmutation area, realization of the full 50 GeV performance of the Main Ring (phase 1 provides 40 GeV), and a neutrino beam line supporting long baseline neutrino experiments.

Performance criteria have been established for all the accelerators and advanced conceptual designs are complete. All major components have been prototyped, and approximately 50% (by cost) are now on order.

The committee heard of a significant scope modification during this meeting—the reduction of the linac energy in its initial implementation to 181 MeV (from 400 MeV). This de-scoping is in response to cost growth that must be accommodated in other areas of the project. Performance implications were discussed, along with the strategy for recovering the full 400 MeV operation once funding becomes available.

The accelerator design and construction present a large number of challenges, most of which are associated with the very high average beam power required from the facility. The design, construction, installation, and (ultimately) commissioning are being under taken by a staff numbering approximately 130 people—an increase of 19 over the last year. While this staff is extremely dedicated and skilled, the committee feels, as it did last year, that the overall staffing is modest for such an ambitious and complex facility, constructed over a six-year time frame.

The committee heard very little on diagnostics and strategies for commissioning of the accelerator complex. This is largely because of the limited available time to cover everything. However, the committee feels that it would be appropriate to delve into these areas at the 2004 ATAC meeting.

Issues Associated with the Lower Linac Energy

The most significant issue discussed at the meeting concerned the decision by J-PARC management to defer implementation of the annular coupled structure (ACS) linac section as a result of a budget shortfall of roughly 8.5 billion yen. As a result, in its initial implementation the linac will have a capability of 181 MeV rather than the 400 MeV in original project scope. The Project Director has assembled an ad-hoc committee to identify a strategy for recovery of the full 400 MeV performance once funding is secured, consistent with projected operational demands for the facility. J-PARC management specifically asked the ATAC for comment on the projected performance of the facility in the lower energy configuration and on the strategy for recovery.

Lowering the linac energy has the most direct impact on performance and configuration of the RCS. It has secondary, but still significant, impact on the performance and configuration of the 50 GeV Main Ring. The primary elements of the complex that have to be addressed in this configuration are:

- **Space-charge forces at RCS injection. The space-charge tune shift scales as $1/(\beta^2\gamma^3)$ for a fixed physical beam emittance (as is created by the RCS injection scheme). Scaling from 400 MeV to 181 MeV would lead to a 66% reduction in beam intensity, and hence beam power, if one maintained the same space-charge tune shift.**
- **The RCS rf system. The frequency swing in the RCS rf system is increased because of the lower injection energy. This is not deemed a significant obstacle. In addition, the RCS will be asked to operate in single bunch mode when filling the 50 GeV Main Ring (see discussion below). Beam loading issues are significantly different with single, as compared to the normal two, bunch operations.**
- **The RCS magnet/power supply system. With 181 MeV injection the magnetic fields in the RCS will be about 64% of their values at 400 MeV. Field quality and power supply regulation at these values need to be understood.**
- **The 50 GeV MR rf system. In order to maintain as much beam intensity as possible in the MR it is proposed to double the harmonic number of the MR rf system and inject single bunches over 15 cycles from the RCS. Implications that must be addressed in the RCS include beam loading compensation with single bunch operations and the duty cycle which can be maintained in the RCS for 3 GeV beam users. Within the MR it is noted that the injection dwell time is increased from 0.16 to 0.60 seconds.**

The J-PARC staff argued, and supported with simulations, the idea that one can operate at a higher space-charge tune shift at the injection energy because a greater fractional beam loss on the collimator can be tolerated. It was estimated that in practice the achievable RCS beam power would be in the range 0.4-0.6 MW when operating in this configuration. It is noted that these numbers

would be further downgraded by 20%, i.e. to 0.32-0.48 MW, when running in the single bunch mode for simultaneous 50 GeV MR operations. It should be noted that a 5% average power reduction in the RCS due to simultaneous 50 GeV MR operations accompanies the original accelerator configuration incorporating the 400 MeV linac.

The recovery scenario developed involves installing the downstream 219 MeV of ACS during 3 month periods executed over three consecutive summer shutdowns, followed by a 3 month commissioning period immediately subsequent to the final installation. The ATAC finds the recovery strategy to be credible. Note that the recovery strategy locks the RCS to MR injection scheme into place, and the accompanying power reduction in the RCS due to simultaneous operations, even after 400 MeV linac operation is achieved.

We also find the strategy for reconfiguring the accelerator complex to accommodate the lower linac energy to be fundamentally sound. However, the committee believes that there is significant uncertainty associated with the performance projections in the interim period in which the linac is operating at 181 MeV and hence makes the following recommendations :

- **Before endorsing completely the proposed scenario for energy recovery, we strongly recommend detailed computation of the performance degradation of the 181 MeV beam when passing through idle detuned ACS structures.**
- **The committee strongly endorses the strategy of completing all civil construction and associated utilities installations to support retrofitting of the full 400 MeV linac energy at a future time.**
- **The committee does not believe the original project goals (1 MW RCS, 0.75 MW MR) can be achieved with the lower energy linac. Hence, the committee strongly encourages management to secure funding to complete the 400 MeV linac at the earliest possible date.**
- **The committee recommends that continued simulations and measurement effort be invested in understanding performance with the 181 MeV linac. In particular we recommend that magnetic fields of RCS magnets be measured at the 181 MeV excitation fields and that consideration be given to non-linear correction elements.**
- **The committee is concerned about the ability of the 50 GeV Main Ring to store beam at flat-bottom over the required 0.6 sec injection time in the presence of strong space charge forces. The committee feels this is a potential vulnerability that requires further investigation.**
- **The committee suggests that commissioning and early operations schedules for J-PARC include realistic assumptions of performance with the 181 MeV linac and the 400 MeV recovery plan.**

Linac

The linac consists of an (H^-) ion source (IS), drift tube (DTL), separated drift tube (SDTL), and annular coupled structure (ACS) linacs. As described above, the ACS construction and implementation is currently delayed. The final energy in Phase 1 (including the ACS linac) is 400 MeV, with a peak current of 50 mA, and a repetition rate of 50 Hz. For 181 MeV operations the peak current is limited to 30 mA due to RCS considerations. The committee notes that this gives the J-PARC staff some additional time to explore options for implementation of the final ion source/RFQ.

The linac design is well advanced and procurement of the DTL and SDTL has begun. An ion source that nearly meets specified requirements also exists and studies of the source and associated low energy beam transport (LEBT) and medium energy transport (MEBT) lines are underway. DTL tanks have been measured and will soon be tested with beam. All recommendations from the May 2002 review have been considered, and some accepted. The committee is happy with the responses. The committee offers the following specific comments and recommendations with respect to the linac, in addition to those listed above relative to the lower injection energy:

- **The design and hardware assembled to date are basically sound and likely to deliver the specified performance.**
- **The end-to-end simulations of the linac are absolutely necessary. We recommend that these be adapted to utilize the observed particle distributions coming out of the ion source and MEBT, and to carry through the entire linac up to the RCS.**

Rapid Cycling Synchrotron (RCS)

The RCS is a state-of-the-art, high power, synchrotron. It is specified as providing a 3 GeV proton beam with 8.3×10^{13} protons per pulse at 25 Hz repetition rate. The total delivered beam power is 1 MW. As discussed above the per pulse intensity is estimated to be at 40-60% of the design intensity while operating with a 181 MeV injection energy.

Multi-turn charge-exchange injection from the linac is utilized in the RCS. Transverse and longitudinal painting, plus a second harmonic cavity, are employed to minimize the impact of space-charge forces within the beam. Acceleration utilizes a novel RF system. The lattice is of the "flexible momentum compaction" type producing a higher transition energy than would be achievable with a more traditional FODO type lattice.

The design lattice for the RCS has been finalized over the last year. Recommendations relative to the design from the May 2002 review have been considered and some adapted, most notably the integration of programmable trim dipoles. Procurements have been initiated and prototype dipoles and quadrupoles fabricated. A prototype rf cavity has been produced and operated at full power and 50% duty factor. The committee commends the project team on an improved injection system relative to that described at the May 2002 meeting. The committee is very favorably impressed by all these developments and offers the following specific comments and recommendations, in addition to those listed above relative to the lower injection energy:

- **The design and hardware assembled to date are basically sound and likely to deliver the specified performance (at the 400 MeV injection energy).**
- **The committee was not presented with detailed impedance and tune-shift budgets for the RCS. The committee recommends that these budgets be developed and requests a presentation at next year's meeting. In addition the committee recommends measurement of impedances of critical components of the RCS, especially the ceramic vacuum chamber.**
- **We recommend a realistic simulation of injection painting and initial ramping incorporating magnetic field errors, space-charge, and collimation.**

50 GeV Main Ring

The 50 GeV Main Ring is the second state-of-the-art, high power, synchrotron in the project. It is specified as providing 50 GeV proton beam with 3.3×10^{14} protons per pulse with a 0.3 Hz repetition rate. The total delivered beam power is 0.75 MW. As discussed above the average beam power is estimated to be at 54-96% of the design intensity while operating with a 181 MeV injection energy into the RCS.

Injection utilizes 15 beam transfers from the RCS (for 181 MeV linac operations). The original design utilized four transfers. Thus, the injection time has been lengthened from 0.16 sec to 0.60 sec. Beam is either fast or slow extracted from the 50 GeV ring in support of a variety of high energy and nuclear physics experiments. The lattice is of the "flexible momentum compaction" type that allows acceleration of the beam without crossing transition. **In phase 1 the energy of the Main Ring is limited to approximately 40 GeV.**

A complete design for the 50 GeV Main Ring exists and procurements of magnets and power supply systems are well advanced. R&D continues in parallel on RF systems. The committee is very favorably impressed by these developments and offers the following specific comments and recommendations, in addition to those listed above relative to the lower RCS injection energy:

- **The design and hardware assembled to date are basically sound and likely to deliver the specified performance (once the 400 MeV linac is operational).**
- **The committee heard a presentation of a proposed design modification that would lower the vertical tune (relative to the horizontal tune) of the MR by 2 units. This change appears well motivated and the committee is happy to add its endorsement.**
- **The discussion provided to the committee on impedances and instabilities represents a good start at understanding these issues within the MR. This effort is in the early stages of development and needs to be continued. The committee recommends that the design team considers the introduction of new elements (for example active dampers or octupoles) or new strategies (increased longitudinal emittance) to combat beam instabilities, especially during the slow extraction process.**
- **The committee is concerned with the performance of the slow extraction from the MR. The scheme presented relies on zero chromaticity and a debunched beam. We believe that beam stability is going to be a serious issue when operating in this mode and thus make the following recommendations: 1)complete the simulation demonstrating the 1% loss criteria during the slow extraction process; 2)simulate the debunching process of the beam in the presence of the cavity impedances; and 3)consider measures to ameliorate beam stability issues during this process, for example through implementation of a higher frequency rf cavity.**

Control System

The J-PARC Control System provides integrated control of the entire complex. **The Control System is based on EPICS and the basic infrastructure is already in place.** The network architecture has been quite fully worked out and includes a fiber backbone to many distributed edge switches with copper to the IOCs and other network devices. This system will operate in a noisy, high pulsed power environment. A small and versatile suite of instruments have been selected that can be interfaced to the control system via Ethernet or the VME backplane. Drivers for these devices have been written and tested.

Specific discussions were held at this meeting concerning the timing, personal protection, and machine protection systems. The committee is favorably impressed with progress to date and offers the following comments and recommendations:

- **The controls team is very small (~9 people) and much of the work will have to be out-sourced. Very tight communication between the two sites will be essential to success.**

- **Based on experience at other laboratories the committee has some concerns relative to the strategy of not locking the timing system to the AC line. The committee recommends the project team consider the impact on non-line-locking on performance of the complex.**