AAC Close-out Report

Fermilab Accelerator Advisory Committee Meeting
May 6 – 8, 2008

***Swapan Chattopadhyay*, Chair**
Cockcroft Institute
United Kingdom

The Committee

Committee members present:

S. Chattopadhyay (Chair, Cockcroft Institute, UK**),** R. Garoby (CERN, Switzerland), K. Harkay (ANL, USA), S. Henderson (ORNL, USA), K-J. Kim (ANL, USA), K. Oide (KEK, Japan), H. Padamsee (Cornell, USA), T. Raubenheimer (SLAC,USA), J. Rosenzweig (UCLA,USA), H. Weise (DESY, Germany)

Apologies:

G. Gecshonke (CERN, Switzerland), I. Ben-Zvi (BNL,USA)

The Charge

The committee was asked to consider and focus on the following FNAL program elements:

(i) Project-X R&D and as it relates to HINS and ILC;
(ii) MUONS;
(iii) A0 Photo-injector and future AARD.

The committee was invited to comment on the overall strategy, appropriateness, goals, timeline, technical progress, organization, mutual alignments, especially between ILC, HINS, MUONS and SCRF and synergy with broader national and international programs.

Additionally, there was the particular request on the scientific potential and intellectual competitiveness of the current program and future upgrades of AARD facility in New Meson Laboratory (NML).

Committee Task Sharing

Project-X (ILC): **H. Padamsee (lead),** R. Garoby, J. Rosenzweig, T. Raubenheimer, K. Oide
HINS**:** **K. Harkay (lead),** S. Henderson, R. Garoby, T. Raubenheimer
MUONS: **R. Garoby (lead)**, S. Henderson, H. Padamsee
A0/AARD: **K-J. Kim (lead),** J. Rosenzweig, H. Weise, K. Oide

1. EXECUTIVE SUMMARY

1.1 Overall comments and observations

The committee received a high level strategic overview of accelerator developments at FNAL from Associate Director Steve Holmes and Deputy Director Y.K.Kim in the context of the present DOE budget and priorities, the directions taken by international projects such as the ILC, and in the light of ongoing strategic panel discussions in P5.

There were well prepared professional talks by the FNAL staff, supplemented by additional talks as requested by the committee. E.g. talks addressing conflicts between various projects, about bottlenecks in performance of Project-X specific accelerators, about consequences of opening up beyond constraints imposed by the ILC and possible reach-out to other communities such as the photon sciences.

The laboratory is trying to adjust to changing budget and shifting US programmatic priorities: the committee applauds the laboratory's strategic approach to such a difficult and challenging task, being nimble and keeping flexibility in mind.

A year ago, the FNAL Steering Group did an excellent job in defining Project-X as the next appropriate step for FNAL in synergy with ILC. In the current review, the AAC was presented with four themes/elements of the laboratory accelerator program: Project-X (HINS), ILC, MUONS and AARD. Compared to past years, only modest technical content was presented this time. This was done so by design with the assumption that the committee was already well versed in the topics. This however posed a bit of a challenge to the committee members, half of whom are new to the committee. Without the benefit of the technical background and without an unambiguous and robust future budget, the committee felt handicapped. However, the laboratory leadership quickly recognized the situation and the FNAL staff responded expeditiously to all additional requests made by the committee to fill in the information needed. The AAC members are thankful for their effort in real time.

Aside from the specific projects (ILC, MUONS, Project-X and HINS), the evolving and potentially unique Super Conducting Radio Frequency (SCRF) and Advanced Accelerator Research and Development (AARD) programs at FNAL can be interpreted as more generic and of general value than just High Energy Physics, being relevant and providing a critical resource to the nation in related developments in other scientific disciplines. The FNAL advanced accelerator facility at NML thus should play the role of a unique national accelerator test facility competitive with existing ones in the nation but offering unique capabilities not duplicated elsewhere.

1.2 Global Recommendations:

The committee is impressed by the continuing strategic thinking and progress made by the FNAL team in this challenging year of shifting priorities and significantly constrained budget. Two high level recommendations can be excerpted from the details to follow:

(i) Significant opportunities exist to harmonize and align different elements of the FNAL program e.g. HINS, Project-X, ILC and MUONS to position the laboratory for the significant future option of high power proton beam driven neutrino/muon research programs. The Committee recommends this integration be given the highest priority at this stage of development.

(ii) Given the unique opportunity to exploit growing SRF infrastructure and competency at Fermilab to create a nationally competitive AARD Program, the Committee recommends higher priority for these activities.

In the following, we provide summaries of the four topics, followed by detailed reports on each by individual teams/task forces in the Appendix.

1.3 Acknowledgement:

Committee thanks FNAL directorate for its total support of logistics with regards to the needs of the committee during this review.

2. Project-X: SUMMARY

2.1 Observations:

The Project-X developed rapidly over the past two years. The completion of CDR in 2010 and Baseline in 2011 are aggressive milestones, but appropriate for FNAL at this time. The Project-X, based on a superconducting linac, is important but, aside from synergy with ILC, hard to justify unless one thinks of the long-term goals of Project-X. In particular one should consider what upgrade potential could be incorporated from the start that would demand and utilize an advanced state-of-the-superconducting linac, for example.

2.2 Technical Concerns:

The committee felt that the technical limitations of aspects due to existing Fermilab accelerator infrastructure other than the linac, e.g. due to existing Recycler and Booster rings, including their aperture limitations, must be made clear. In this context, the AAC already urged accelerator physics studies of performance limitations of the rings last August (2007). Issues such as the expected level of beam loss due to space-charge, electron-cloud and other instabilities, etc., the necessary cures if any including space-charge neutralization of the electron-cloud, replacement of the existing beam pipe with coated beam pipes, etc. should be investigated in detail as part of detailed study of the technical and scientific reach of Project-X.

2.3 Recommendations:

(i) It is desirable that the future 8 GeV SC linac be upgradeable to satisfy needs of future users of high beam power at 8 GeV, in order to surpass capability of other options (e.g. Rapid Cycling Synchrotrons). Capability for the upgrade to multi-MW version should be reviewed in detail.

(ii) Low energy front ends tend to have a longer life-time in large facilities. So a basic design of the low energy front end should accommodate a large dynamic range of future options.

(iii) Synergy with the ILC needs to be re-evaluated. There are limitations imposed by the adoption of the ILC systems, which may be detrimental towards development of a neutrino/muon facility later on, if needed. This limitation in terms of peak current, repetition rate, pulse length, etc. must be articulated properly.

(iv) Perform and keep for future reference a “shadow-study” of an ideal high power 8 GeV linac without the constraints of the ILC parameters and technology. How would it look in terms of frequency, no. of cells/cavity, no. of cavities, the number and length of cryomodules, and cost? This will be important at the CD-2,-3 level to defend this approach.

(v) Identify potential future users of Project-X beyond the present vision (e.g. Muon Collider community) and communicate to Project-X team.

(vi) We endorse an inclusive integration of external collaborating institutions and resources into the Project-X master plan by the laboratory leadership.

3. HINS: SUMMARY

3.1 Observations:

HINS was originally designed as a front end for a multi-MW Proton Driver, based on a 60 MeV superconducting linac and continues to make steady progress. The conception and design of the room temperature and superconducting spoke-cavities are technically sound. Due to historical reasons, the project appears to be run independent from Project-X, despite the fact that it directly addresses its low energy front end, arguably the most difficult and risky aspect of a high power 8 GeV linac. One should note that the HINS parameters are more ambitious than those for Project-X, capable of driving the Project-X to reach its ultimate parameters delivering 2 MW beam power at 8 GeV.

3.2 Concerns:

The Committee feels that not enough details have been presented in the talks to decipher the presence of adequate diagnostics/instrumentation to verify and demonstrate the main goals. The amplitude and phase responses appear to be too slow. It is not clear whether these can be fixed properly. Yet a second concern aside from technical issues above is the affordability and efficiency of a stand-alone HINS program in its current mode without adding value synergistically to other programs in the laboratory such as the ILC, Project-X, MUONS, AARD, etc. Finally the last concern is that of cost of the project and planned contingencies, if any. HINS are a $50M class project. Are there back-up plans, should HINS fail to deliver on its ambitious performance goals?

3.3 Recommendations:

(i) HINS needs to couple more strongly to Project-X. There is an opportunity here to direct HINS more to help Project-X achieve its goals. In particular, there is significant need to understand performance requirements from HINS towards Project-X.

(ii) It is essential to develop diagnostics and instrumentation to calibrate HINS performance. The monitoring of emittance growth, halo formation and overall evolution of 6-D phase space are all critical, since most damage to the beam would have happened by 100 MeV in any linac system.

(iii) The low energy ends tends to have longer life-time in most facilities. So a basic design for the low-energy end should accommodate a large dynamic range in order to support future options.

(iv) It is also important to develop a back-up plan for Project X utilizing conventional room temperature front end.

4. ILC: SUMMARY

4.1 Observations:

The re-scoping of ILC activities, given national priorities, appears to be appropriate. The use of the funding towards developing Super Conducting Radio Frequency (SCRF) capability with a focus towards Project-X as a priority, while satisfying ILC priorities albeit in a slightly different order as proposed, is probably appropriate for the lab at this time. The reduced scope of NML seems correct given funding limitations.

4.2 Recommendations:

(i) The stand-alone cryomodule test stand is important for both ILC and Project-X. The Committee recommends maintaining this basic functionality and retain clear goals.

(ii) The committee believes that the test-stand should be ready to accept beams for testing, but should not be over-emphasized as essential as this may be to the detriment of otherwise essential AARD activities (more later on this under AARD section).

5. MUONS: SUMMARY

5.1 Observations:

The FNAL is one of the original institutions pioneering Muon Collider studies. In July 2006, laboratory director initiated Muon Collider Task Force (MCTF) to take a major lead in this direction. Many novel and innovative developments have taken place since then taking advantage of the laboratory's core competencies. The Muon program was recently reviewed by MUTAC. The goal of developing a feasibility study, a Reference Design Report (RDR), a detailed plan and a cost estimate by 2012 appears reasonable.

5.2 Concerns:

It is not clear to the Committee how real the design concepts are without engineering developments. It is Important to find at the earliest a solution to the limitation of the electric field in the RF cavity due to high magnetic fields. The committee also recognizes the need for enhanced resources in this area.

5.3 Recommendations:

(i) Detailed simulations of the major components with errors should be done.
(ii) The Committee strongly recommends that the foreseen requirements for the proton driver of a future Muon facility be taken into account in the design of Project-X right from the start.
(iii) Develop a very clean cost model as the facilities design matures.

6. A0 and Advanced Accelerator Research: SUMMARY

6.1 Observations:

The Committee notes the excellent work to date performed in advanced accelerator research and development by the FNAL team, with modest budget and support from the lab management. The small AARD group has excellent team-spirit and has focused on a few outstanding topics with visible impact e.g. generation and transport of 'flat' beams, dynamics of emittance exchange etc. The group has demonstrated that FNAL has relevant competencies and expertise to develop an AARD facility in NML. But the Committee feels that this lean effort needs augmentation from the laboratory itself, in addition to the excellent collaboration with other laboratories and universities (e.g. NIU, ANL,TTF/DESY, etc.) as demonstrated by the team. The Committee also feels obliged to point out that there exist severe intellectual competition from other institutions that are already advanced in this area. Hence laboratory investment should be very carefully considered to enhance those areas where it adds complementary and uncontested value.

6.2 Recommendations:

(i) Develop a unique program based on targeted areas of excellence and existing unique technology infrastructure, intellectually competitive with other national facilities.

(ii) The Committee recommends that the old (and existing) A0 Program Committee be reconstituted and revitalized in order to help prioritize and rate the highest value-added programs which will add new knowledge in critical areas and not revisit the past.

(iii) The AARD program is advised to set some project specific goals in order to add relevance and value to the laboratory's prioritized projects (e.g., generation of 'flat beams' should be targeted at ILC or CLIC requirements etc., offering glimpses of significant cost reduction via elimination of Damping rings, say or provide alternate designs).

(iv) The Committee recommends further decoupling of AARD from the ILC/Project-X operational constraints in order to let it flourish, while retaining capacity to add value to these projects by providing appropriately formatted pulses for testing modules with beams.

(v) The Committee recommends that the laboratory leadership empower the A0 R&D team with resources, financial and organizational support, and strengthen its intellectual leadership in a nationally competitive scenario.

(vi) Enhanced recruitment to strengthen intellectual leadership is highly recommended.

7. APPENDICES

7.1 APPENDIX A: Review Agenda, May 6-8, 2008

7.2 APPENDIX B: AAC Charge

7.3 APPENDIX C: Comment on Project-X/ILC

7.4 APPENDIX D: Comment on MUONS

7.5 APPENDIX E: Comment on MUON activities at FNAL

7.6 APPENDIX F: Comment on A0 and AARD

APPENDIX A

7.1 Fermilab Accelerator Advisory Committee Agenda

May 6-8, 2008
Comitium, Wilson Hall 2SE
Revision 16-April-2008

Tuesday, May 6

8:30-9:00	Committee Executive Session	S. Chattopadhyay
9:00-9:15	Welcome and Presentation of Charge	S. Holmes

Project X

9:15-10:00	Project X Design and Development Plan	D. McGinnis
10:00-10:25	Project X Resource Requirements	E. McCluskey
10:25-10:50	Break	
10:50-11:10	Project X Collaboration Plan	S. Holmes

ILC

11:10-11:50	ILC Cavity and Cryomodule Development Plan	R. Kephart
11:50-12:30	Discussion	
12:30-1:30	Lunch	

HINS

1:30-2:00	HINS Status and Plans	G. Apollinari
2:00-2:30	HINS Facility: Testing and Commissioning	R. Webber
2:30-2:50	Discussion	
2:50-3:10	Break	

Muons

3:10-3:30	Overview of Muon Activities at Fermilab	S. Geer
3:30-4:05	NFMCC Activities at Fermilab	A. Bross
4:05-4:40	MCTF Activities	A. Jansson
4:40-5:00	Discussion	
5:00-6:30	Committee Executive Session. Requests for supplementary or breakout presentations on Wednesday	
7:00	Dinner	

Wednesday, May 7

AARD

8:30-9:30	Experimental AARD Activities at Fermilab's A0 Photoinjector	R. Fliller
9:00-9:30	Plans and long-term vision for AARD at Fermilab	P. Piot
9:30-9:45	Discussion	
9:45-12:00	Supplementary presentations and/or breakout discussions as requested by the committee. Committee Executive Session	
12:00-1:00	Lunch	
1:30-5:00	Supplementary presentations and/or breakout discussions as requested by the committee. Committee Executive Session	

Thursday, May 8

8:30-11:00	Committee Executive Session
11:00-12:00	Closeout
12:00	Adjourn

APPENDIX B

7.2 Charge to Fermilab Accelerator Advisory Committee

May 6-8, 2008

Charge (Draft Rev. 4)

The Fermilab Accelerator Advisory Committee is asked to look at a variety of activities supporting the Fermilab strategic plan for the post-Tevatron era. The primary topics for review and discussion are:

1. Project X R&D Plan

Fermilab has prepared a Project X R&D Plan aimed at supporting all activities required to complete a technical, cost, and schedule baseline (CD-2 in the language of DOE) by the end of 2011. This plan is integrated with R&D programs running in parallel on ILC, SRF Infrastructure, and High Intensity Neutrino Source (HINS). It is also desirable to develop the design of Project X in a manner that retains the opportunity for future utilization in a muon-based facility (Neutrino Factory or Muon Collider).

The Committee is asked to review and offer comments and recommendations relative to the Project X R&D plan, including the overall strategy, the appropriateness of program goals, timeline, organization, and alignment with the ILC, SRF, HINS, and Muon programs.

2. Fermilab Muon Program

The Muon Collider initiative is organized through the Muon Collider Task Force (MCTF) at Fermilab. Activities of the Neutrino Factory and Muon Collider Collaboration (NFMCC) and MCTF are closely coordinated, with NFMCC concentrating on Neutrino Factory design and simulation, and experimental efforts on targeting (MERIT) and 4-D cooling (MICE); and the MCTF concentrating on Muon Collider design and simulation, and technology development for 6-D cooling arrangements that would be applicable to a MC.

The Committee is asked to review the activities of the MCTF and NFMCC activities at Fermilab, and offer comments on the strategic approach, the appropriateness of program goals (including with respect to timing), and the technical progress towards achieving these goals. The committee should note that the national Muon program will have been reviewed by the Muon Technical Advisory Committee four weeks before the AAC meeting. As such the AAC is specifically asked to concentrate on Fermilab's contributions to these programs. In formulating its comments and recommendations the committee should consider, and offer advice as appropriate, on the interaction between these activities and the broader national and international muon programs.

3. Photoinjector Program and Future Directions.

The photoinjector program, currently situated in the A0 laboratory, is under consideration for relocation to the New Muon Lab (NML) in support of beam testing of 1.3 GHz cryomodules sometime in the 2012 timeframe. This relocation could offer the opportunity for a new program of advanced accelerator R&D operating in parallel with cryomodule testing. Such a program could be based on the upgraded photoinjector and/or the 750 MeV electron beam that would be made available via the operation of a complete ILC/Project X RF unit at NML. The committee will be presented with an outline of facility characteristics, an overall scientific strategy, and possible AARD program elements.

The Committee is asked to review the scientific potential for AARD based on the currently configured facility, and possible facilities at NML. We are particularly interested in the Committee's comments and recommendations relative to the following:

- Comment on the competitiveness, nationally and internationally, of potential science programs in each of three scenarios:
    - The current configuration with possible modest upgrades
    - A 50 MeV capability in NML
    - A 200-750 MeV capability in NML
- For each scenario, which program elements seem most compelling?

As usual the committee is invited to issue comments or suggestions on any aspect of the programs discussed beyond those specifically included in this charge. It is requested that a concise report responsive to this charge be forwarded to the Fermilab Director by July 1, 2008.

Thank you

APPENDIX C

7.3 Comments on Project-X / ILC

H. Padamsee (Lead), J. Rosenzweig

7.3.1Findings/Commendations

The Committee commends the FNAL team for successful completion and qualification of many crucial segments of the SRF infrastructure e.g. vertical test facility, clean room facility, CM assembly facility, preparations for testing CM at the New Muon Lab (despite funding constraints). The Committee commends the injector studies under way.

7.3.2 Important Milestone

First CM assembled with DESY and INFN collaboration.

7.3.3 Recommendation – 1

Above activities are essential first steps toward the eventual goal of a rapid CM production rate (1/month). The Project X is a National Collaboration with excellent coupling to expertise in national labs and universities. The Committee recommends maintaining focus on completion and qualifying the processing facility by maintaining strong coupling with the XFEL SRF production activities and the ILC SRF activities towards revised goals of S0, S1, and S2. The Committee also recommends FNAL to continue to build and solidify the Project-X collaboration, with attention to updating the existing SRF and ILC collaborations in the Project-X context. In this context, holding more regular collaboration meetings on Project X topics would be beneficial.

7.3.4 Recommendation -2

Project X modules will be somewhat different from ILC modules. It is recommended to assemble a comparison table of Project-X and ILC modules both at 9ma peak current parameter set e.g. all Project-X modules have a quadrupole gradient > 24 MV/m. It is also recommended to consider whether to decouple specific CM activities from ILC due to such differences e.g. evaluate the need for Type IV CM for Project-X. In the near-term, Project-X should be viewed synonymously with ILC.

7.3.5 Recommendation -3

A longer term evolution will involve possible upgrades. It is possible that Project-X will evolve to higher beam power at 8 GeV in order to fulfill future physics needs. It is recommended that FNAL identify potential future users of the 8 GeV beam e.g. Neutrino factory, and Muon collider and define their needs and communicate to the designers of Project-X. One should rrevisit technical choices in the design of the sc linac and of the overall facility, taking these future needs into account. Therefore it is recommended to examine *at an early stage* to what extent the baseline ILC design and technology can be extended to meet the higher beam power need which will involve: higher peak current; rep rate 5 Hz to 10 Hz (as for the XFEL); longer pulse length to accommodate more bunches; lowering operating temperature to 1.9 K to raise the operating Q; higher average power couplers. As Project-X evolves in these directions the design philosophy should be revisited. The performance/cost of re-alignment of the 8 GeV linac should be thoroughly evaluated. In particular, the 8 GeV linac design should be evaluated with higher emphasis on compatibility with high power upgradeability for application to muons/neutrinos.

7.3.6 Recommendations-4

Prepare a layout of the conceptual design of Injector up to 420 MeV, based o spokes, squeezed elliptical cavities etc. As the results of HINS are potentially critical for Project-X and its upgrades, the coupling between the two projects should be strengthened..

7.3.7 Recommendations-5 (Rings)

The technical limitations due to existing recycler and booster rings should be made clearer, including the aperture, beam loss due to space charge, electron cloud instabilities. In this context, one should note that even the base line case is non-trivial. Capability for the upgrade to multi MW version should be reviewed. Investigate in more detail about what kind of electron cloud phenomena will be expected and what level of suppression will be necessary to cure them. Explore what kind of studies should be planned. Investigate which of the single-bunch, coupled-bunch, and coasting beam instabilities matter(s) and whether coating existing beam pipes provide any mitigation of the effects. Possible neutralization of the space-charge effect by electron clouds at the low energy end should be explored.

7.3.8 Concluding Remarks

In order to coordinate the diverse aspects of Project-X (including evolutionary paths), and the associated personnel resources it demands, the directorate should develop, along with the division management, a plan for implementing Project-X while preserving pre-existing laboratory commitments as much as possible.

APPENDIX D

7.4 Comments on Muon activities at FNAL

R.Garoby (lead), *S. Henderson, H.Padamsee*

7.4.1 Foreword

FermiLab has been a co-founder of the Muon Collider Collaboration more than a decade ago. The pioneering work it triggered has generated highly productive ideas and rendered possible the concept of a neutrino factory at the change of century. The collaboration was renamed to Neutrino Factory and Muon Collider Collaboration (NFMCC) in 2000 to reflect this evolution. FNAL coordinated the first feasibility study of such a facility.

In July 2006, the FermiLab director initiated the Muon Collider Task Force (MCTF) to complement the work accomplished by the NFMCC for neutrino factories and to boost progress towards a multi-TeV Muon Collider. New subjects could then be addressed, like powerful 6D phase space cooling.

Tight coordination is achieved by the Muon Collider Coordinating Committee.

7.4.2 Findings

In the context of the NFMCC, FNAL is making substantial contributions, namely concerning:
- the MUCOOL program (development and test of cooling system components),
- the MICE experiment at RAL,
- fundamental design and simulation work in support of the Neutrino Factory International Design Study.

Notable efforts in the recent past include the demonstration of high gradient in pressurized as well as in vacuum operating RF cavities and the development of solid absorbers for ionization cooling using LiH.
The work on RF operation at high gradient in the presence of a magnetic field is of interest for the whole accelerator community. Progress on the front of the understanding of the breakdown mechanism and its cure is especially valuable. This is typically illustrated by the remarkable achievement, in collaboration with JLab, of a 19 MV/m gradient without field emission in a clean 200 MHz cavity. Moreover, a record of 14 MV/m was obtained in the fringe field of a large aperture 2.5 T solenoid.

The MCTF work is meant to offer an alternative option for a lepton collider in the next few years. It has already been at the origin of impressive progress on muon-collider issues:
- exploration of 6-D cooling channel concepts,
- collider ring lattice studies,
- prototyping of coils for an HCC,
- HTS cable studies.

The MTA beamline will soon be operational. It will enable testing pressurized RF cavities at high gradient in the presence of beam.

A 5 year plan coordinating NF and MC activities is being prepared for August 2008, with the goal of proving in 2012 a feasibility study for a Muon Collider and a Reference Design Report for a Neutrino factory. It foresees:

- the completion of the MICE experiment,
- answers/solutions on key RF questions,
- the preparation of a coherent design of a Muon Collider,
- significant progress on the front of HTS use and in the exploration of the possible alternatives for muon acceleration.

These achievements cannot be obtained at constant funding: progressively increasing resources (up to $ 25M/year) will therefore be requested.

7.4.3 Comments & recommendations

Considering the number of technical topics and their complexity, the resources invested in developments for neutrino factory and muon collider appear fairly modest. Remarkable progress has nevertheless been obtained, and **the AAC acknowledges that the work contributed by FNAL covers a broad range of subjects** (absorbers, pressurized RF cavities) **and estimates that it can be qualified as:**

- **new and innovative** (specificity of the needs),
- **unique** (no duplication),
- **making a good use of the lab's capabilities** (beam in MTA, RF competence…).

The new physics results foreseen around the year 2012, both from LHC and from the present neutrino experiments make it important to know at that date about all possible options for future frontier HEP facilities. The availability of a feasibility study for a Muon Collider and of a Reference Design Report for a Neutrino Factory will allow for an analysis taking properly these possibilities into account.
FermiLab being earmarked as the only HEP US laboratory of the future, it is especially important that it prepares for hosting the new project by contributing significantly to that analysis. **Therefore the AAC fully agrees with the proposal to prepare an MC feasibility study and the RDR of a Neutrino Factory for 2012.**

The 5 year plan that will be submitted in August 2008 has to explain the planning and the resources necessary for reaching that goal. **Although detailed justifications are not yet available, the Committee nevertheless concurs that substantially increased resources will be required to meet this challenge.**

Moreover, the Committee strongly recommends that the foreseen requirements for the proton driver of a future muon facility are taken into account in the design of Project-X.

APPENDIX E

7.5 Comments on HINS

K. Harkay (lead), *S. Henderson, R. Garoby, T. Raubenheimer*

7.5.1 Findings

The HINS R&D project continues to make steady progress towards building a unique 60 MeV superconducting linac. The linac is designed to be room temperature (RT) up to 10 MeV, followed by superconducting (SC) up to 60 MeV. The technology choices in part have been driven by local interest and expertise as well as by a desire for synergy with other high-intensity linac R&D projects such as FRIB (ANL/MSU), JPARC (KEK), and SPL (CERN). HINS is designed to be a front end for a multi-MW proton driver, with initial beam power 0.5 MW, upgradable to >2 MW.

The HINS R&D team is to be commended on their results to date. These include the successful redesign and re-machining of the RFQ to address assembly problems; fabrication and tests of the RT spoke cavities (including low and high power rf tests); and fabrication and tests of the first SC spoke cavity. The demonstration of the SC spoke cavity gradient is especially a notable achievement. Initial operation is planned with a proton source, while H- source development continues in parallel.

The primary customer for HINS is now Project X (PX). HINS can either be a front end for PX or be an upgrade path for PX for a multi-MW beam. The decision on whether to use HINS technology or more conventional warm technology for the PX front end is expected to be made in 2010. According to the HINS commissioning plan overview that was presented, the committee notes there is a possible schedule mismatch between the PX decision point and the projected HINS 60 MeV demo in late 2011. To date, the HINS schedule has been driven partly by M&S and partly by effort allocation; the committee notes that the original goal of a 90-MeV demonstration has been downscaled to 60 MeV due to the budget.

7.5.2 Links with PX

At the moment, the HINS project and PX appear to be uncoupled; this needs to be improved. There is an opportunity to strengthen the link between the HINS effort and PX. There is a need to understand the real performance requirements for HINS from PX. That is, HINS R&D should be aimed directly at PX beam parameters; for example, a beam demonstration with PX-targeted parameters in time to impact the PX decision.

There is a clear value to building a low-energy injector early for testing. Generally, the most difficult and risky aspect of an 8 GeV linac is the low-energy end; this is directly addressed by the HINS effort.

The HINS beam parameters are in fact more aggressive than those included in the initial Project X goals. There is an opportunity to take advantage of the HINS goals to drive the ultimate beam parameters for Project X: potentially delivering 2 MW of beam power at 8 GeV. Injectors typically have a longer lifespan than high-energy machines; it would be advantageous from the beginning to adopt an injector design that is compatible with a possible multi-MW PX upgrade. For example, a linac designed for 27 mA could operate initially at 9 mA, with some specifications possibly relaxed. Clearly the feasibility of a multi-MW PX upgrade needs to be evaluated in detail; this is discussed elsewhere.

Recommendations:

- Develop HINS R&D milestones and demonstration goals in more detail, as well backup plans, especially in the context of synergy with PX parameters and milestones
- Consider adopting HINS design features that are compatible with a potential multi-MW PX upgrade

7.5.3 Technical issues

The committee did not hear many technical presentations at the review, and we look forward in the future to hearing more details related to components such as the chopper, modulator amplitude/phase control, and the proton source. For example, the chopper drive signal has ripples; this needs work. Also, the amplitude/phase response seems too slow; does the PS upgrade fix this?

Since one of the stated goals of HINS is to demonstrate a front-end that could be used for Project X, it is essential to determine whether the beam quality is adequate and suitable for use as an injector to the 8 GeV linac. The committee feels that beam diagnostics and instrumentation is a central issue and requires more focus than it is presently receiving. In particular, since most of the "damage" to the beam has occurred by 100 MeV, it is essential to measure in the HINS demo the emittance growth, halo development, and 6-D characterization of the output beam parameters.

Recommendations:

- Address potential technical issues relating to the chopper and modulator amplitude/phase control
- Develop a beam diagnostics and instrumentation plan for HINS to evaluate beam quality suitable for PX

APPENDIX F

7.6 Comments on AARD Program at A0

Kwang-Je Kim(Lead), *J. Rosenzweig, H. Weise*

7.6.1 Performance

The AARD performance to date has been admirable, highlighted by the following few chosen metrics:

(i) Unique beam physics experiment:
- Flat beam generation &EEX: phase space manipulation;

(ii) Training of accelerator physicists:
- One Ph.D per year!

(iii) Seeding of new technologies for FNAL:
- SCRF for acceleration and deflection, 1.3 and 3.9 GHz;
- Lasers for beam generation and diagnostics;

(iv) Uniqueness of beam physics experiments:
- Flat beam generation &EEX: phase space manipulation.

7.6.2 Opportunities and Uncertainties with the postponement of A0 Move to NML

The beam physics experiments can be pursued uninterrupted, refined, and diversified, until 2011, with energy upgraded to 40 MeV and improved diagnostics, if the move is postponed. With the move to NML in 2012, however, the "A0" has a potential to become a major AARD center with an energy reach for the electrons of up to 500-700 MeV. However, an element of uncertainty exists as the future direction of FNAL is not solidified yet.

7.6.3 Plan for 2008- 2011

Upgrades in energy to 40 MeV, in diagnostics, and to incorporate a new gun will enable high-impact beam physics experiments, e.g.
- Achieving 'flat' beam aspect ratio >1000, EEX with smaller emittance beams, positron gun, image charge undulator, electro-optics, 20 fs TOF monitor, dielectric acceleration in slab geometry;

The A0 AARD program can be strengthened by:
- Targeting the flat-beam and EEX R&D for the ILC and CLIC projects;
- Restarting the A0 Program Committee.

7.6.4 After Relocation to NML in 2012

With possible decoupling from ILC operational testing, the injector and beamline may need to be re-configured to maximize the capability:

- Redistribution of bunch compressors and diagnostics between accelerator modules should be considered.

Develop a broadly-based AARD program with 500-700 MeV energy upgrade, including also non-HEP area such as light source development:

- Manipulation and measurement of ultra-low emittance;
- Large charge/pulse and high rep rate;
- Gamma ray production with Compton backscattering, etc.

7.6.5 AAC Recommendations

(i) AAC endorses A0 aspiration to become a center for AARD research inviting collaboration from other labs and university groups

(ii) This will require the commitment of resources and funding on AARD research by the FNAL management

(iii) A0 operation with a higher productivity and visibility will require an improved organizational structure