Interim Report

Krishna Kumar, UMass Amherst
NSAC meeting, June 30 2011

On behalf of the 2011 NSAC Subcommittee on Fundamental Nuclear Physics with Neutrons

Response to Charge Letter (11/29/10) from DoE Office of Science and NSF MPS

Outline

- **Background for the Neutron Charge**
  - *Formation and procedures of the subcommittee*
- **nEDM experiment**
  - *Findings and 6 recommendations*
- **Fundamental physics with neutron beams**
  - *Findings and 3 recommendations (by physics topic)*
- **Primary prioritized list of initiatives in neutron science at constant level of effort**
- **Comments on the subfield**
  - *Additional findings and one final recommendation*

Charge Elements: Background

- **NSAC LRP 2002**
  - *invest in a new neutron beamline at the SNS*
- **2003 subcommittee recommendations**
  - *launch nEDM*
  - *construct beamline and support program of measurements*
- **Agencies response**
  - *Construct FNPB at the SNS*
  - *R&D investment for neutron EDM experiment*
  - *Launch nEDM project: CD-0: Dec ‘05, CD-1: Dec ’06*
- **NSAC LRP 2007**
  - *Neutron physics part of targeted program of symmetry tests of the New Standard Model, and precision EW physics*

Charge Elements: Guidelines

- **Evaluate current and proposed research program**
  - *physics potential in the context of the larger FS subfield*
  - *scientific capabilities and specific opportunities*
  - *international context*
- **Recommendations of priorities in context**
  - *projected resources; constant level of effort at FY2011 levels*
  - *identify most compelling opportunities*
  - *review infrastructure and effort required*
  - *both US and international capabilities as backdrop*
  - *priorities for incremental investments beyond constant level*
  - *assessment of current scientific and technical workforce*

Neutron Physics Themes

- **nEDM experiment**
  - *compelling physics case in larger context*
  - *significant fraction of funding and effort*
- **Weak Interactions with Neutrons**
  - *lifetime is a fundamental parameter*
    - ***current results inconsistent at the 1 s level***
  - *correlations comprehensively probe neutron charged weak current*
    - ***evaluate in larger context based on sensitivity to BSM physics***
  - *hadronic parity violation*
    - ***fundamental description of non-leptonic weak interactions***
  - *Experimental program*
    - ***Evaluate recent progress: degree of difficulty vs physics payoff***

Subcommittee Formation & Activities

- **Late December to late January**
  - *sought guidance from agencies and senior physicists in subfield*
  - *Sent invitations to committee members (100% success rate!)*
- **February/March**
  - *launched subcommittee teleconferences: self-orientation*
  - *formulated a plan of work centered around three meetings*
    - ***first 2 meetings were "fact-finding" with focus on US program***
    - ***third meeting: closed meeting to converge on priorities***
- **April: Two open meetings near Chicago O'Hare**
  - *April 1-2: focus on nEDM experiment & closed session orientation from agencies*
  - *April 15-16: Rest of Neutron Physics*
- **May/June**
  - *teleconferences to discuss priorities and findings*
  - *June 11: resolution meeting in Seattle to converge on principal recommendations*

Subcommittee Membership

Professor Hartmut Abele
Technische Universität Wien (Vienna)
Atominstitut der Ősterreichischen Universitäten

Professor Alejandro Garcia
Department of Physics
University of Washington

Professor John Hardy
Department of Physics & Astronomy
Texas A&M University

Professor Wick Haxton
Department of Physics
University of California, Berkeley

Professor David Hertzog
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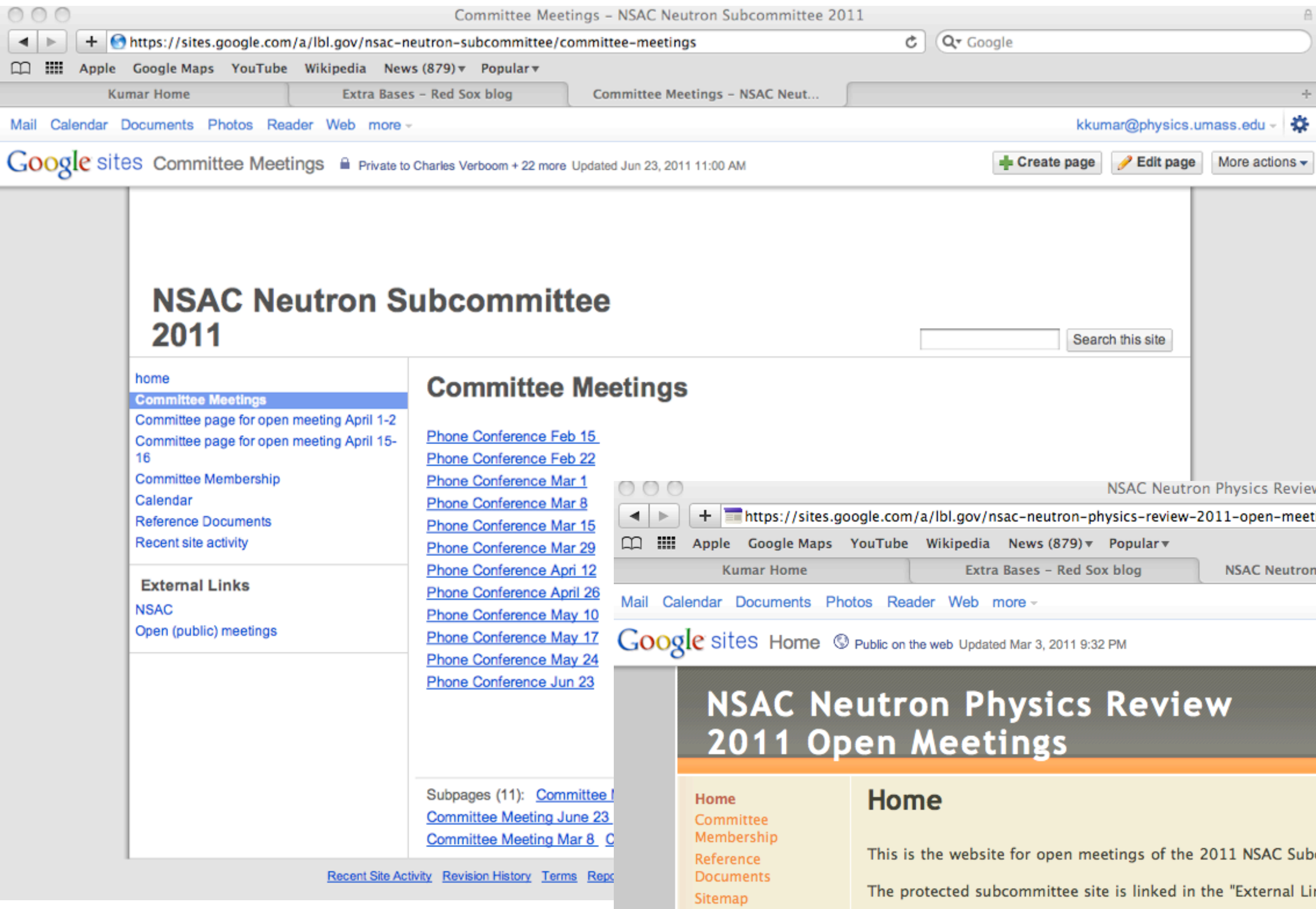
Physics Division
Argonne National Laboratory

Professor Michael Ramsey-Musolf
Department of Physics
University of Wisconsin

Professor Michael Romalis
Department of Physics
Princeton University

thanks to P. Jacobs and LBL!

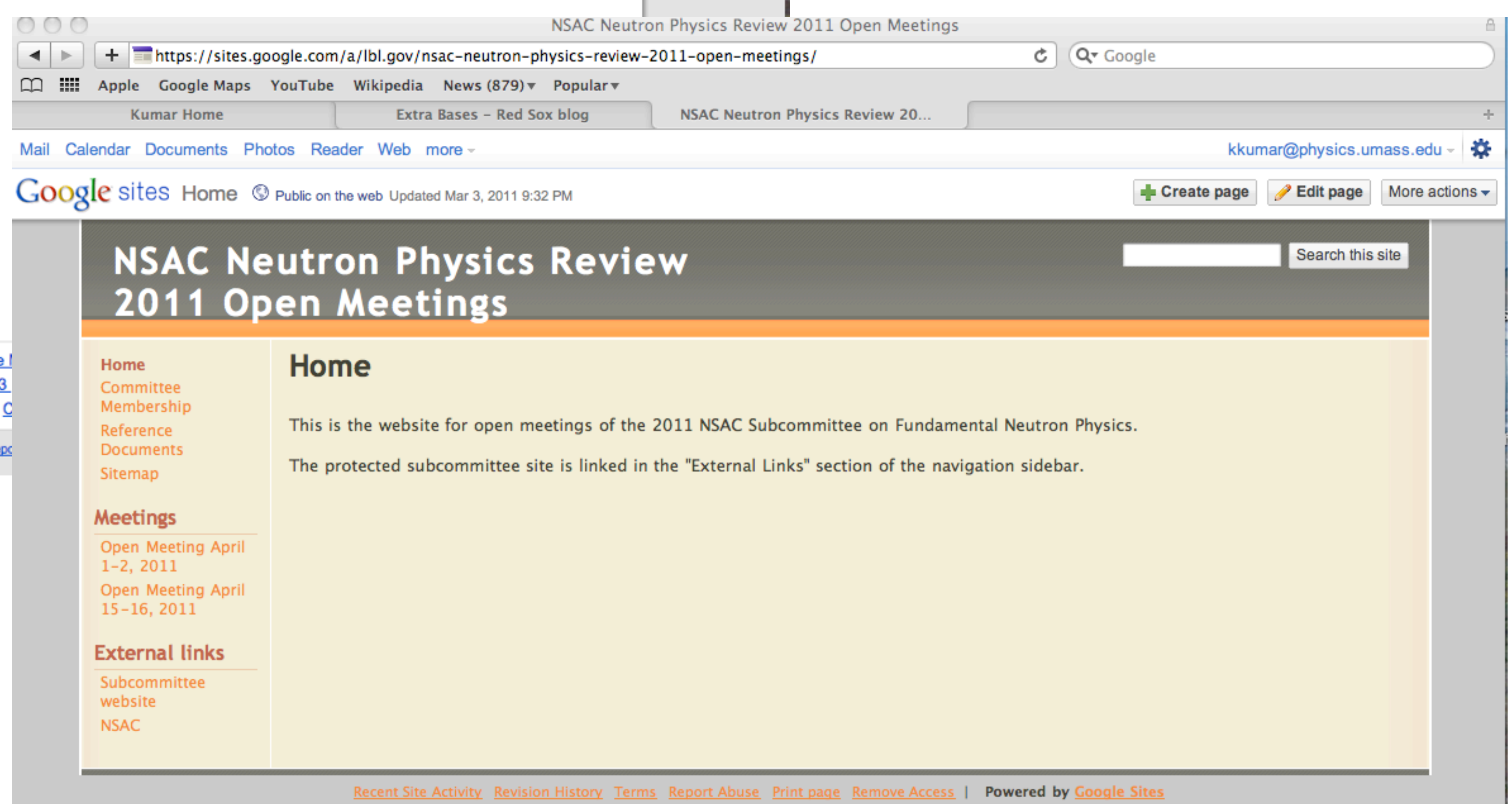
Web Resources



Private Google Site for subcommittee

12 Internal Teleconferences

also attended by G. Henry and B. Keister



Public Site for open meetings: logistics, talks *nEDM meeting*

April 1-2

Friday April 1

Agenda

	duration			Speaker	talk length
8:00	1:00	9:00	Executive session		
9:00	1:30	10:30	Science and experiment overview	P. Huffman	60
10:30	0:15	10:45	break		
10:45	0:30	11:15	Statistical errors	B. Filippone	20
11:15	0:45	12:00	systematic errors	T. Ito	30
12:00	1:30	13:30	Executive session		
13:30	0:52	14:22	R&D Overview	M. Cooper	35
14:22	0:37	15:00	3He and Cryogenic Highlights	D. Beck	25
15:00	0:30	15:30	Break		
15:30	0:37	16:07	HV Studies in Liquid He	J. Long	25
16:07	0:30	16:37	Prototyping of B0 Magnet System	A.P. Galvan	20
16:37	0:22	17:00	MC Simulation of EDM Signal	B. Plaster	15
17:00	1:30	18:30	Executive session		
18:30	0:15	18:45	Overnight Homework assignment		

Saturday April 2

8:00	0:30	8:30	Collaboration response to questions; Q&A		
8:30	0:45	9:15	International Context	B. Filippone	30
9:15	0:30	9:45	FNPB Context	G. Greene	20
9:45	0:37	10:22	Cost and Schedule Overview	V. Cianciolo	25
10:22	0:22	10:45	Optimizing nEDM Proj. Management	G. Capps	15
10:45	0:30	11:15	Break		
11:15	0:30	11:45	Collab. Responsibilities/commitments	R. Redwine	20
11:45	1:00	12:45	Executive session		
12:45	0:30	13:15	Closeout with Collaboration		
13:15	4:00	17:15	Executive session		

← *4 hour executive session laid out plan of work*

Process after Presentations

- **Subcommittee evaluation of nEDM status**
  - *several teleconferences*
    - ***technical status of each subsystem***
    - ***project, physicist manpower, engineering manpower***
  - *responses sought for several technical questions from nEDM*
  - *findings summarized in internal document*
- **Seattle meeting**
  - *Reviewed findings*
  - *Drafted recommendations*

We now present our findings and recommendations regarding the nEDM experiment

Neutron EDM Overview

- **Physics Motivation for a neutron EDM**
  - *Search for a non-zero EDM: signature of T-violation*
  - *Search for new physics in early universe; explore baryogenesis scenarios*
  - *Fundamental test of the symmetries of the Standard Model*
- **Community Endorsement**
  - *2002 LRP and 2003 Neutron Subcommittee's strong support*
  - *Significant investments in R&D for next generation experiment*
  - *New beamline: FNPB at ORNL*
  - *Recommendation 3 in 2007 LRP singled out T-violation searches*
- **We find the motivation for sensitive EDM searches, including neutron EDM, to be as compelling as ever**

Neutron EDM Priority

The successful completion of an nEDM experiment, the initiative with the highest scientific priority in US neutron science, would represent an impressive scientific and technical achievement for all of nuclear physics, with ramifications well beyond the field

nEDM Overview

Findings

- **nEDM conceptual design is novel**
  - *large active volume: gain statistical sensitivity to 1-10x10^{-28} e-cm*
  - *several novel techniques to explore unknown new systematics*
  - *only concept aimed directly at exploring a new regime of sensitivity*
- **nEDM reach is nominally estimated at 4x10^{-28} e-cm**
  - *such reach would have profound impact beyond subfield even if negative*
  - *even if reach is ~10x10^{-28} e-cm, still worth doing at current scope so long as final results and publications are produced before 2025*
- **Design has progressed over last few years**
  - *Feasibility studies of physics concepts driving experimental design*
  - *several technical challenges have been resolved*
  - *First-pass engineering design*
- **International competition (ILL, PSI)**
  - *intermediate steps about an order of magnitude less sensitive (50x10^{-28})*
  - *however, estimated to have faster turnaround time (5 years)*
  - *in the 10 year time frame, they expect to compete at the same level*

Current Status of nEDM

Findings

- **Significant further R&D is required**
  - *Fundamental physics concepts related to measurement techniques validated, but important details still being worked out*
  - *Several key aspects of the measurement technique remain unproven under true experimental conditions: HV breakdown limit, electric field monitoring, electrode coating, and total photoelectron yield per signal event*
- **The subcommittee feels that the collaboration needs:**
  - *A singular focus on outstanding R&D issues*
  - *Better coordination and communication across various teams*
  - *Improved support for large scale cryo-engineering*
  - *Improved communication and support from ORNL and LANL*

After extensive deliberation of the progress and needs, the subcommittee formulated 6 recommendations to define a path forward

Recommendation 1

- **Successful resolution of R&D items of paramount importance**

1) We recommend a restructuring of the collaboration's scientific and technical management to enable greater coherence of the scientific, engineering and R&D efforts.

- **A well-structured and strategically targeted R&D plan is needed**
  - *bulk of research effort should go towards a "full-court press" on the major technical challenges in the measurement technique*
  - *redirection from focus to obtain construction funding*

Recommendation 2

- **The collaboration has many talented and diverse research groups**
  - *Expertise is needed in an unusually broad set of techniques*

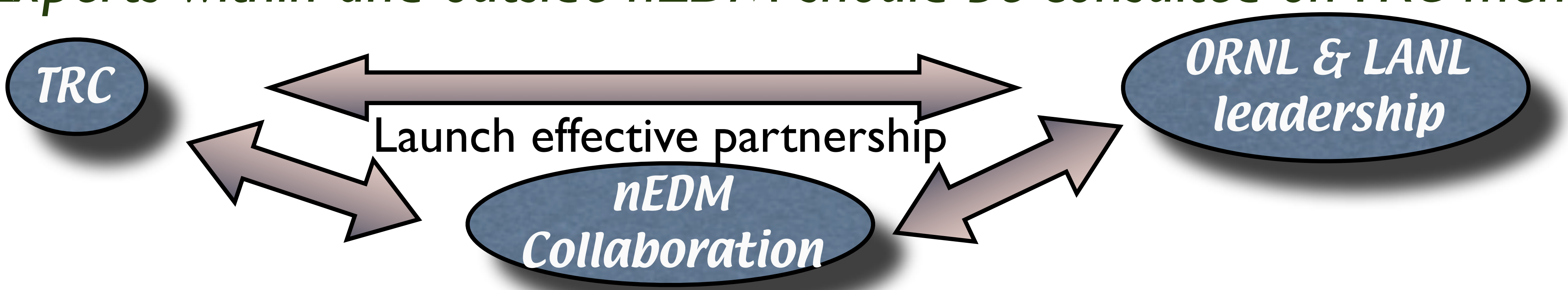
2) We recommend that the collaboration fully exploit all expertise necessary to resolve the primary R&D issues as part of this reorganization, possibly including individuals outside the current collaboration.

- **Improved coordination and continuous communication needed among physicists performing R&D, physicists and engineers designing the apparatus, and collaboration leadership**
  - *avoid significant future reengineering and retrofitting as R&D evolves*
- **Key PI's: need 80-100% of research effort on nEDM now**

Recommendation 3

3) We recommend that ORNL and LANL jointly establish an external standing Technical Review Committee (TRC) to review the R&D progress and to report periodically to the management of both institutions.

- **The TRC's primary focus would be to monitor technical progress and to evaluate mitigation of technical risk**
  - *Experts within and outside nEDM should be consulted on TRC membership*



- **Ensure resources promptly redeployed as needed**
- **Large magnitude and scope: increased and sustained institutional commitment from ORNL, and continued significant support from LANL are both needed**

Recommendations 4 & 5

4) We recommend that large procurements be contingent upon resolution of the major outstanding technical issues, as determined by the TRC.

- **Focus on R&D, but engineering could use time efficiently**
  - *cryogenic system is unusually large in scale and low in temperature*
  - *seek technical expertise/advice from NP accelerator/physics divisions:*
    - ***centralization and improved coordination of all engineering***
    - ***additional expertise on large-scale cryo-engineering***

5) We recommend that the agencies provide continued support for a period of two years given implementation of the aforementioned recommendations.

- **Time & flexibility to evaluate & solve technical problems**
  - *In the interim, neither the design configuration nor the cost of the central detector system should be assumed to be stable*

Neutron EDM Priority

The successful completion of an nEDM experiment, the initiative with the highest scientific priority in US neutron science, would represent an impressive scientific and technical achievement for all of nuclear physics, with ramifications well beyond the field

Recommendation 6

- **We estimate that there is a 2-year window to initiate construction, given international competition and evolution of related physics topics**

6) We recommend, in the event that major outstanding R&D issues remain unresolved after two years, that consideration be given to discontinuing the Major Item of Equipment (MIE) Project and re-evaluating the approach to measurement of the neutron EDM.

Neutron Physics Meeting
Agenda

April 15-16

Friday April 15					
Start	**Duration**	**End**		**Speaker**	**Talk Duration**
8:00	1:00	9:00	Executive session		
9:00	0:30	9:30	NIST Facilities Perspective	M. Arif	20
9:30	0:30	10:00	LANL Facilities Perspective	S. Wilburn	20
10:00	0:30	10:30	ORNL Facilities Perspective	G. Greene	20
10:30	0:15	10:45	Break		
10:45	1:15	12:00	UCNA, B, b	A. Young	50
12:00	1:35	13:35	Executive session/lunch		
13:35	0:50	14:25	The Nab/abBa/PANDA program	D. Pocanic	35
14:25	0:25	14:50	Polarization and Polarimetry in abBA/PANDA	T. Chupp	15
14:50	0:25	15:15	aCORN	F. Wietfeldt	17
15:15	0:25	15:40	NIST radiative decay	R. Cooper	17
15:40	1:20	17:00	Executive session		
17:00	0:30	17:30	NIST trap-based lifetime	H. P. Mumm	20
17:30	0:25	17:55	NIST beam-based lifetime	J. Nico	17
17:55	0:25	18:20	LANL UCN lifetime	A. Saunders	17
18:20	1:00	19:20	Executive Session		
Saturday April 16					
Start	**Duration**	**End**			
8:00	1:00	9:00	Executive Session		
9:00	0:15	9:15	What will we learn from HWI	D. Bowman	10
9:15	0:24	9:39	NPDgamma	D. Bowman	16
9:39	0:25	10:04	n-4He spin rotation experiment at NIST	M. Snow	17
10:04	0:25	10:30	n-3He experiment at SNS	C. Crawford	17
10:30	0:30	11:00	Break		
11:00	0:30	11:30	emiT + future D-coefficient	J. Wilkerson	20
11:30	0:45	12:15	neutron interferometry	M. Huber	30
12:15	1:00	13:15	Executive Session/lunch		
13:15	0:15	13:30	Closeout		
13:30	3:30	17:00	Executive session		

3.5 hour executive session to set priorities

Overview

- **Fundamental neutron physics**
  - *Neutron beta decay part of global search for BSM physics*
    - ***electroweak interactions at quantum-loop level***
    - ***search for clues to symmetries of the early universe***
  - *Hadronic parity violation*
    - ***fundamental and unique insight into nucleon dynamics***
  - *Neutron interferometry*
    - ***many practical applications***
    - ***neutron charge radius and few-body scattering lengths***
- **Significant progress over last decade**
  - *Several important new results*
  - *technical progress: poised to capitalize on recent investments*

The subcommittee formulated three recommendations on the highest priority initiatives covering the first two topics above
NOTE: Recommendations 7, 8 & 9 DO NOT represent a rank ordering

Recommendation 7

- **The neutron lifetime is a fundamental parameter**
  - *Impacts many areas of nuclear & particle physics and cosmology*
  - *Current thrust is to improve consistency to a precision of 1s*
  - *Well-motivated long term goal is to achieve a precision of 0.1 s*

7) We recommend that high priority be given to acquiring new data with the cold beam-based lifetime measurement at NIST, following its planned improvements.

- **Primary findings**
  - *A robust beam-based lifetime measurement at 1s precision is very timely*
  - *A magneto-gravitational trap using UCNs aims to reach 0.1s in the long term*
    - ***substantially more R&D would be required to demonstrate viability***
  - *The NIST effort using magnetically trapped UCNs is not competitive*
  - *The research groups would benefit from better communication & collaboration*
    - ***work together to chart out the most effective future R&D strategies***

Recommendation 8

- **Neutron beta decay correlation coefficients fundamentally important**

8) We recommend continued support for the UCNA experiment at LANL to improve the measurement precision of the A-coefficient by exploring a cost-effective and expeditious path to the original design sensitivity of 0.2%. We further recommend parallel R&D to develop the experiment to measure the a-coefficient with the Nab spectrometer, with a sensitivity of 0.1%.

- **Primary findings**
  - *A- and a-coefficients measure g_A/g_V; impacts many subfields*
    - ***strong motivation to pursue fractional accuracy of 0.1% in the long term***
    - ***aCORN at NIST will provide an intermediate step (~ 1%)***
    - ***Nab should provide an order of magnitude improvement in the long term***
  - *B- and b-coefficients have interesting sensitivity to BSM physics*
    - ***R&D for future measurements could be explored; long term goal of 10^{-4}***
    - ***Full-scale UCNB and abBA/Panda projects should be revisited in few years***

Recommendation 9

- **Hadronic Parity Violation: study strangeness-conserving hadronic weak interactions**
  - *Nuclear decay: dynamical suppression of long-range N-N weak interactions*
  - *NPDGamma at SNS seeks to confirm this interpretation*
    - ***fundamental strong-weak interaction interplay vs many-body dynamics***

9) We recommend strong support for the NPDGamma experiment as the highest priority measurement in hadronic parity-violation, and urge that every effort be made to reach the design goal, an asymmetry determination of one part in 10^8.

- **Additional Findings**
  - *Other significant investments: await the success and outcome of NPDGamma*
    - ***n-^{3}He: development could continue as R&D; further technical review warranted***
    - ***n-^{4}He motivation and technical feasibility should be reviewed in a few years***

Priorities

- **Subfield is vibrant; many excellent initiatives proposed**
  - *But there is neither the money, people or time to do everything*
- **Highest priorities spelled out below in rank order**

1. *nEDM is the highest priority for neutron science*
   - ***specific set of recommendations (#1 thru #6) crafted; goals and timelines specified***
2. *continue UCNA to its logical end i.e. achieve original design goals (#8)*
   - ***build on existing investments and expertise***
3. *complete NPDGamma and ensure the design precision is reached (#9)*
   - ***the beamline is ready and preparations for the experiment are progressing well***
4. *invest in Nab (only project needing new funding) (#8)*
   - ***next precision instrument for neutron beta decay; several years of development***
5. *complete modest lifetime effort (NIST cold beam): poised for 1s precision (#7)*
   - ***Measurements worldwide inconsistent; NIST cold beam effort is very mature***
   - ***the future goal is 0.1 s, likely with UCNs, but US initiatives still in R&D stage***

- ***The program above fits into a funding scenario of constant effort***
- ***2 thru 5 are part of the numbered recommendations 7, 8 and 9***

Additional Findings

- **Other completed and ongoing projects**
  - *New result from emiT at NIST is the best limit on the T-violating D-coefficient*
  - *Neutron interferometry has many practical applications*
    - ***particularly interesting are recent results on the neutron charge radius and few-body spin-independent and -dependent scattering lengths, and ongoing improvements***
    - ***cost largely independent of the purview of the present Charge***
- **US workforce insufficient to carry out all proposed initiatives**
  - *Recommendations have singled out highest priorities*
  - *R&D recommended (potentially) for some other initiatives (see recommendation 10)*
  - *Urge active participants to direct resources to the highest priority initiatives*
- **US facilities & capabilities are world-class, with excellent opportunities**
  - *NIST: steady productivity, projected increase in neutron flux and a new beamline*
  - *FNPB (CD-4 on schedule & on budget): new pulsed cold beam poised for first data*
  - *LANL: steady increase in the flux of usable UCNs*
  - *Many technical innovations and excellent training environment for young scientists*

Recommendation 10

- **However, we find that coordination of scientific effort and utilization of resources available not optimal at present**

10) We recommend that consideration be given to establishing a standing committee to review and prioritize various initiatives in US fundamental neutron science.

- **Provide guidance to agencies, national labs, and the physics community:**
    - *initiation of scientific prioritization of new initiatives*
    - *guidance on allocation of R&D funds*
    - *Improved collaboration across research groups: techniques and instrumentation*
    - *optimization of neutron beams; mitigation of redundancies at various facilities*
    - *improved communication to the broader physics community on the role of neutron measurements in the exploration of fundamental symmetries*

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  - *improved communication to the broader physics community on the role of neutron measurements in the exploration of fundamental symmetries*

It is possible that the optimum strategy is broader:
a standing committee to encompass all aspects of
Fundamental Symmetries and Neutrinos in nuclear physics.

Concluding Remarks

- **A very active subfield**
  - *Thanks to the speakers: outstanding talks showing the physics potential and the technical progress of various initiatives*
  - *Fundamental neutron science will remain an important part of the larger subfield of Fundamental Symmetries in the foreseeable future*
- **Thanks to my subcommittee colleagues!**
  - *They brought a wealth of experience to bear on the broader physics issues as well as the technical details*
  - *They stayed closely engaged throughout the process*
  - *They followed, as well as led, at just the right moments*
- **Thanks to Gene Henry and Brad Keister for patiently listening and also patiently answering our questions**
- **I personally hope that the subcommittee's efforts will lead to the best science moving forward**