Performance Measures Progress Report

NSAC Meeting Washington, D.C.

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NSAC Charge Letter excerpt

- **Activities across the federal government are being evaluated against established performance goals. In FY 2003, utilizing input from NSAC, the long-term goals for the DOE SC Nuclear Physics program and the metrics for evaluations of the program activities were established. It is timely during this long range planning exercise to gauge the progress towards these goals, and to recommend revised long-term goals and metrics for the DOE SC Nuclear Physics program, in the context of the new LRP, if appropriate. The findings and recommendations of this evaluation should be a separate report.**
  - **(from NSAC charge letter of July 17, 2006 requesting new Long Range Plan)**

Who Are We?

- Larry Cardman (Jefferson Lab)
- Robert Janssens (Argonne)
- Curtis Meyer (Carnegie-Mellon)
- Hamish Robertson (U. Washington)
- Brad Sherrill (Michigan State U.)
- Bira van Kolck (U. Arizona)
- Steve Vigdor (Brookhaven)
- Glenn Young (Oak Ridge)

Previous Report

- **Previous effort requested September 12, 2003; report submitted November 18, 2003**
  - **S. Aronson, B. Balantekin, L. Cardman, R. Casten (ex officio), B. Filippone, D. Geesaman (chair), J. Harris. W. Nazarewicz, S. Wallace**
- **Report can be downloaded from**
  - **http://www.sc.doe.gov/np/nsac/docs/nsac_report_performance_measures.pdf**
- **Proposed four Performance Measures**
- **Gave 41 Milestones, grouped into 5 major areas, as means of measuring progress towards the four performance measures**

OMB Performance Measures

- **Does the program have a limited number of specific long-term performance measures that focus on outcomes and meaningfully reflect the purpose of the program?**

- **Purpose of above question: to determine if the program has long-term performance measures to guide program management and budgeting and promote results and accountability. The question seeks to assess whether the program measures are salient, meaningful, and capture the most important aspects of the program purpose and appropriate strategic goals**

- **Elements of a "Yes" answer: A Yes answer would require identifying a limited number (e.g. 2 or 3) of specific, easily understood program outcome measures that directly and meaningfully support the program's purpose. A "performance measure" is an outcome of an output measure. Long term is defined as a relatively long period of time relative to the nature of the program but is likely to be on the order of 5-10 years and consistent with time periods for strategic goals used in the Agency Strategic Plan.**

OMB Performance Measures

- **2003 Long Term Performance Measures addressed four areas**
  - **Hadronic Physics**
  - **Physics of High Temperature and High Density Hadronic Matter**
  - **Nuclear Structure and Nuclear Astrophysics**
  - **Neutrinos, Neutrino Astrophysics and Fundamental Interactions**
- **Two-tier grading scheme, each with enumerated physics goals**
  - **"Minimally Effective"**
  - **"Successful", which is a superset of Minimally effective**
- **Timeframe – by 2015**
- **Expert review every five years rates progress as "Excellent" , "Good", "Fair" or "Poor"**

Revised Rating Scheme for Performance Measures

- Add definition of what the measure means
- Note why the measure is important
- Four levels
  - Excellent (superset of Good)
  - Good (achieve three specific outputs)
  - Fair (achieve two of the three)
  - Poor (achieve one of the three)
- Expert review every five years to rate progress towards above levels
  - 2003 panel suggested twice the frequency of Long Range Plans, which would be every three years
  - Up to others in this room…

Example of a Performance Measure – 2007

- **Taken from "Physics of High Temperature and High Density Hadronic Matter"**
- **Recreate brief, tiny samples of hot, dense nuclear matter to search for the quark gluon plasma and characterize its properties**
  - **Timeframe – By 2015**
  - **Expert Review every five years rates progress as "Excellent", "Good", "Fair" or "Poor"**
  - **Successful – 1) The existence of a deconfined, thermalized medium is determined; 2) its properties such as temperature history, equation of state, energy and color transport (via jets), and screening (via heavy quark production) are characterized.**
  - **Good – 1) The existence of hot, high-density matter is established; 2) some of its properties (e.g., its initial temperature via the photon spectrum) measured; 3) confinement properties, and energy transport (via jets) are explored.**
  - **Fair – Supported research leads to modest outputs in only two of the three goals described in the "Good" rating.**
  - **Poor – Supported research leads to modest outputs in only one of the three goals described in the "Good" rating.**

NSAC Milestones

- **Indicators of key steps towards achieving performance measures**
- **Necessarily implies selection from a broader range of results; emphasis on representative set without unnecessarily binding to specific facilities**
  - **"The milestones for xxx Physics include representative examples of progress in each these aspects without being inclusive of all relevant work."**
- **Budget assumptions are necessary, as facilities and personnel which are/will be available determine which milestones can be met**
- **2003 report listed 41 as representative; others could have been chosen**
- **Timeline extended to 2013 for most**
- **Difficult but achievable in aggregate**
- **We propose to extend the timeframe and to reflect new capabilities and priorities from current LRP**
- **Review whether those thru 2007 were met, evaluate progress towards and/or revise those in the future**
  - **We like published references in refereed journals to help back up an evaluation**
- **Any changes establish precedent for evolving milestones, thus**
  - **Important to document our reasons**
  - **Important to revise/add/subtract as appropriate to reflect dynamic nature of scientific research**

Milestone Grading Guide – Past (≤2007)

- **Exceeded: We achieved the milestone as written AND overachieved (either by reaching the milestone early or by carrying out additional, related research that further addresses the issue, or by completing the studies so thoroughly that one can regard the matter as settled definitively).**
- **Achieved: The milestone was achieved as planned, but we did not "exceed the goal" in any substantive way.**
- **Not Fully Achieved: We did not finish on time, but the bulk of the planned research was completed, we have made progress toward addressing the physics goals, and the effort will be finished (to the "good" level) within a year or two of the planned date. (Note: comment on why we didn't make it - funding limitations, technical problems, etc.)**
- **No Significant Progress: We did not meet the milestone, and are not likely to complete the work to the "good" level in the foreseeable future without a significantly increased effort. (Here, comment on why we didn't achieve the milestone.)**

Milestone Grading Guide – Future (≥2007)

- **Exceeded: On track to fully achieve milestone, either earlier than anticipated or with additional, related research on the topic completed, or with progress (and/or incremental studies planned) such that we are confident that the issues will be regarded as settled definitively.**
- **Achieved: On track to achieve milestone as anticipated, but not likely to have made substantive additional progress.**
- **Not Fully Achieved: Achieving the milestone to the "good" level on the timescale planned is at risk without an increased effort (Note: comment on why we're not likely to make it - funding limitations, technical problems, etc.)**
- **No Significant Progress: Achieving the milestone to the "good" level on the timescale planned is not likely without substantially increased effort. (Here, comment on why we are unlikely to achieve the milestone)**

Sample Milestone Evaluation

- **Hadronic Physics Milestone M1 (2008): Make measurements of spin carried by the glue in the proton with polarized proton collisions at center of mass energy, √sNN = 200 GeV.**
- **What has been accomplished toward milestone M1 and what has been learned from the information gathered?**
  - RHIC has been commissioned as the world's only polarized proton collider. Polarized proton collision experiments have so far been carried out at 200 GeV in 2002-6, with luminosity and beam polarization increasing year by year. The best constraints on the gluon contribution to the proton's spin come from helicity correlations measured for the abundant channels leading to inclusive neutral pion and jet production (with the PHENIX collaboration providing the best measurements for the former, and the STAR collaboration for the latter, channel). Already published results[1] from the 2003-5 RHIC runs, rule out gluon contributions larger than the proton's spin, which were speculated in the 1990's to be responsible for the rather small net spin carried by quarks. Much tighter constraints come from the so far preliminary analysis of 2006 results by PHENIX and STAR, both interpreted within the context of a given model for the dependence of gluon polarization on the fraction of the proton's momentum carried by the gluon. The results are consistent with zero gluon polarization, but still allow for small positive or substantial negative (opposite the proton spin) contributions to the proton spin. They do not rule out gluon helicity preferences that change sign as a function of the gluon's momentum fraction.
- **What remains to be done to complete the original milestone as written?**
  - The experiments measure helicity correlations. Information on gluon polarization is extracted from these and other measurements within the context of a perturbative QCD analysis. Robust results on the gluon contribution to the proton spin, with proper accounting for systematic errors associated with the theoretical treatment, await global analyses (now being launched) of the full relevant nucleon spin structure database, including the RHIC spin results. In addition, coincidence measurements (jet-jet and photon-jet) are needed to probe the dependence of gluon polarization on momentum fraction more sensitively than is possible with the inclusive data acquired to date.

[1] S.S. Adler *et al.* (PHENIX Collaboration), Phys. Rev. Lett. 93, 202002 (2004) and Phys. Rev. D 73, 091102(R) (2006); A. Adare *et al.* (PHENIX Collaboration), Phys. Rev. D 76, 051106(R) (2007); B.I. Abelev *et al.* (STAR Collaboration), Phys. Rev. Lett. 97, 252001 (2006) and arXiv:0710.2048

Sample Milestone Evaluation (continued)

- **Hadronic Physics Milestone M1 (2008): Make measurements of spin carried by the glue in the proton with polarized proton collisions at center of mass energy, √sNN = 200 GeV.**
- **What additional/new data should be taken (or theoretical efforts modified or added) to address the underlying scientific question?**
  - The measurements to date at 200 GeV are primarily sensitive to gluons carrying between a few and 30% of the proton's momentum. Gluons carrying even lower momentum fractions are highly abundant and, if even slightly polarized, could contribute substantially to the proton's spin. Sensitivity to such softer gluons requires additional coincidence measurements at 500 GeV proton-proton collision energy and/or at more forward production angles. Data for other production channels (e.g., heavy flavor production) can also serve as crosschecks on the robustness of the pQCD interpretation.
- **Is the milestone complete? No**
  - Excellent progress has been made, but the milestone is not quite completed. In light of what has been learned to date, a more focused update of the milestone is as follows:
  - **Utilize polarized proton collisions at center of mass energies of 200 and 500 GeV, in combination with global QCD analyses, to determine if gluons have appreciable polarization over any range of momentum fraction between 1 and 30% of the momentum of a polarized proton.**
  - It should be feasible to complete the updated milestone by 2013.
  -
- **Bottom line status assessment: Achieved**

Sample Milestone Summary (partial) for an Area (Nuclear Astrophysics)

- **2007: Measure transfer reactions on r-process nuclei near N=50 and N=82 closed shells**
  - Completed on time, several examples given, full scope covered**, Rating: Achieved**
  - A new milestone to extend this are is proposed**: 2014 Perform mass measurements and nuclear reaction studies to infer weak interaction rates in nuclei in order to constrain models of supernovae and stellar evolution.**
- **2009: Measure properties of and reactions on selected proton-rich nuclei in the rp-process to determine radionuclide production in novae and the light output and neutron star crust composition synthesized in X-ray bursts**
  - Tremendous progress, large body of relevant measurements, over dozen published measurements and papers on e.g. burst modeling and light curve shape, completed two years early. **Rating: Exceeded**
  - A new milestone should reflect the next step, to infer information on the astrophysical sites**: 2014 Measure or constrain key nuclear reaction rates to improve accuracy of astrophysical models of novae and X-ray bursts and allow astronomical data to be used to infer novae and neutron star properties.**
- **2011: Measure neutron capture reactions, including radioactive s-process branch-point nuclei, to constrain s-process isotopic abundances.**
  - Current progress is good (ten sample references given). Many more neutron-capture reactions rates on both radioactive and stable nuclei still need to be measured. In particular many more measurements on radioactive samples must be completed (review quoted)**. Rating: Achieved**

Examples of Milestones We Propose to Revise (1)

- **Hadronic Physics M2 2008: Extract accurate information on generalized parton distributions for parton momentum fractions, x, of 0.1 – 0.4, and squared momentum transfer, t, less than 0.5 GeV^2 in measurements of deeply virtual Compton scattering**
  - Helicity-dependent and independent cross sections have been measured over the x_B and t range specified; an accurate measurement of the Q^2 dependence over limited range shows dominance of "handbag" mechanism. This is a prerequisite for using DVCS to probe structure of proton that is parametrized by GPDs.
  - Substantial incremental data in hand (on neutron) and major theory effort has advanced understanding.
  - Full statistics of CLAS beam-spin-asymmetry experiment (1/3 in hand) will complete FY08/09, with better statistics than foreseen, even for rather high Q^2. Delay due to H.Isabel and budget limitations that slowed restoration of high energy capability and required reduced operations**.**
- **Modified milestone M2: Measure the helicity-dependent and target-polzarization-dependent cross-section differences for deeply virtual Compton scattering off the proton and the neutron in order to extract accurate information on generalized parton distributions for parton momentum fractions, x, or 0.1 – 0.4, and squared momentum transfer, t, less than 0.5 GeV^2.**
  - Should be feasible to complete by 2012**. Rating : Not Fully Achieved**

Examples of Milestones We Propose to Revise (2)

- **Nuclear Structure M5 2010: Complete initial measurements with the high resolving power tracking array, GRETINA, for sensitive studies of structural evolution and collective modes in nuclei.**
  - Prototype built and tested, on-bench and in-beam. Tracking algorithms demonstrated. Performance targets on energy and position resolution met. Initial milestone written 2003 was dated two years after projected 2008 completion, but prior to necessary formal project approvals. DOE CD-2/3 now received.
  - Work on gamma-ray-tracking has spurred outside activity in gamma-ray imaging, with uses in DHS and medical imaging.
  - CD4 planned FY2011, with in-beam operation soon after. Two years for data-taking and analysis allowed in proposing revised date of 2013.
- **Modified milestone 2013: Complete initial measurements with the high resolving power tracking array, GRETINA, for sensitive studies of structural evolution and collective modes in nuclei.**
  - **Rating : Not Fully Achieved**

Examples of Milestones We Propose to Revise (3)

- **High Temperature, High Density Hadronic Matter M4 2009: Perform realistic three-dimensional numerical simulations to describe the medium and the conditions required by the collective flow measured at RHIC.**
  - Briefly, in 2003 we did not expect the evidence to point to a strongly-coupled, near-perfect fluid
  - The ideas about existence of fundamental lower limits to the ratio of viscosity to entropy density were new, or not even that yet
  - Focus of theoretical efforts has to reflect this
- **Modified milestone 2011: Perform realistic three-dimensional numerical simulations to describe the medium and the conditions required by the collective flow measured at RHIC and to quantify the viscosity of the nearly perfect fluid.**

Example Summary Table (Hadronic Physics)

Year	New #	Old # (ref.)	Milestone
2009	M1	M3	Complete the combined analysis of available data on single π, η, and K photo-production of nucleon resonances and incorporate the analysis of two-pion final states into the coupled-channel analysis of resonances.
2010	M2	M4	Determine the four electromagnetic form factors of the nucleons to a momentum-transfer squared, Q^2, of 3.5 GeV^2 and separate the electroweak form factors into contributions from the u, d and s-quarks for $Q^2 < 1$ GeV^2 .
2010	M3	M5	Characterize high-momentum components induced by correlations in the few-body nuclear wave functions via (e,e'N) and (e,e'NN) knock-out processes in nuclei and compare free proton and bound proton properties via measurement of polarization transfer in the $^4\vec{H}\,e(\vec{e},e\vec{p})$ reaction.
2011	M4	M6	Measure the lowest moments of the unpolarized nucleon structure functions (both longitudinal and transverse) to 4 GeV^2 for the proton, and the neutron, and the deep inelastic scattering polarized structure functions $g_1(x,Q^2)$ and $g_2(x,Q^2)$ for x=0.2-0.6, and $1 < Q^2 < 5$ GeV^2 for both protons and neutrons.
2012	M5	M7	Measure the electromagnetic excitations of low-lying baryon states (<2 GeV) and their transition form factors over the range $Q^2 = 0.1 -$ 7 GeV^2 and measure the electro- and photo-production of final states with one and two pseudoscalar mesons.
2012	M6	update of old M2	Replacement/Update proposed: Measure the helicity-dependent and target-polarization-dependent cross-section differences for deeply virtual Compton scattering off the proton and the neutron in order to extract accurate information on generalized parton distributions for parton momentum fractions, x, of 0.1 – 0.4, and squared momentum transfer, t, less than 0.5 GeV^2.)
2013	M7	M8	Measure flavor-identified q and $\bar{q}$ contributions to the spin of the proton via the longitudinal-spin asymmetry of W production.
2013	M8	update of old M1	Proposed Replacement: Utilize polarized proton collisions at center of mass energies of 200 and 500 GeV, in combination with global QCD analyses, to determine if gluons have appreciable polarization over any range of momentum fraction between 1 and 30% of the momentum of a polarized proton./Update proposed)
2014	M9	M9	Perform lattice calculations in full QCD of nucleon form factors, low moments of nucleon structure functions and low moments of generalized parton distributions including flavor and spin dependence.
014	M10	M10	Carry out ab initio microscopic studies of the structure and dynamics of light nuclei based on two-nucleon and many-nucleon forces and lattice QCD calculations of hadron interaction mechanisms relevant to the origin of the nucleon-nucleon interaction.

New Milestones

- **Hadronic Physics**
  - **2018: Extract accurate information on spin-dependent and spin-averaged valence quark distributions to momentum fractions x above 60% of the full nucleon momentum**
  - **2018 The first results on the search for exotic mesons using photon beams will be completed.**
- **High Temperature/High Density Matter**
  - **2012: Measure fluctuations and related indicators in global observables and bulk properties of Au + Au collisions at √sNN from 5 to 30 GeV to search for evidence of a critical point in the QCD matter phase diagram.**
  - **2014 Measure jet and photon production and their correlations in A≈200 ion+ion collisions at energies up to √sNN = 3.5 TeV.**
  - **2016 Measure production rates, high pT spectra, and correlations in heavy-ion collisions at √sNN = 200 GeV for identified hadrons with heavy flavor valence quarks to constrain the mechanism for parton energy loss (in the quark-gluon plasma).**
  - **2018 Measure real and virtual photon production in p + p, d + Au and Au + Au collisions at energies up to √sNN = 200 GeV.**

New Milestones (continued)

- **Nuclear Structure**
  - **2015: Measure properties and production mechanisms of the elements above Z~102 to understand the nature and behavior of these nuclei, and to assist theoretical predictions for the structure and production of superheavy elements.**
  - **2016: Measure changes in shell structure and collective modes as a function of nucleon number and angular momentum from proton-unstable to neutron-rich nuclei in order to develop new nuclear paradigms and guide theory in every region of the theoretical road map.**
- **Nuclear Astrophysics**
  - **2014: Perform mass measurements and nuclear reaction studies to infer weak interaction rates in nuclei in order to constrain models of supernovae and stellar evolution.**
  - **2014: Measure or constrain key nuclear reaction rates to improve accuracy of astrophysical models of novae and X-ray bursts and allow astronomical data to be used to infer novae and neutron star properties.**
- **Neutrinos, Neutrino Astrophysics, Fundamental Interactions**
  - **2018: Obtain initial results from an experiment to extend the limit on the electric dipole moment of the neutron by two orders of magnitude**

Milestone Evaluations (draft)
Hadronic Matter (1)

Year	Milestone	Complete?	Status Assessment
2008 M1	Make measurements of spin carried by the glue in the proton with polarized proton-proton collisions at center of mass energy, $\sqrt{s_{NN}}$ = 200 GeV. (Replacement/Update proposed)	No	Achieved
2008 M2	Extract accurate information on generalized parton distributions for parton momentum fractions, x, of 0.1 - 0.4 , and squared momentum change, –t, less than 0.5 GeV^2 in measurements of deeply virtual Compton scattering. (Replacement/Update proposed)	No	Not Fully Achieved
2009 M3	Complete the combined analysis of available data on single π, η, and K photo-production of nucleon resonances and incorporate the analysis of two-pion final states into the coupled-channel analysis of resonances.	No	Not Fully Achieved
2010 M4	Determine the four electromagnetic form factors of the nucleons to a momentum-transfer squared, Q^2, of 3.5 GeV^2 and separate the electroweak form factors into contributions from the u, d and s-quarks for $Q^2 < 1$ GeV^2 .	No	Exceeded
2010 M5	Characterize high-momentum components induced by correlations in the few-body nuclear wave functions via (e,e'N) and (e,e'NN) knock-out processes in nuclei and compare free proton and bound proton properties via measurement of polarization transfer in the $^4He(\vec{e},e\vec{p})$ reaction.	Yes	Achieved
2011 M6	Measure the lowest moments of the unpolarized nucleon structure functions (both longitudinal and transverse) to 4 GeV^2 for the proton, and the neutron, and the deep inelastic scattering polarized structure functions $g_1(x,Q^2)$ and $g_2(x,Q^2)$ for x=0.2-0.6, and $1 < Q^2 <$ 5 GeV^2 for both protons and neutrons.	No	Exceeded

Milestone Evaluations (draft)
Hadronic Matter (2)

2012 M7	Measure the electromagnetic excitations of low-lying baryon states (<2 GeV) and their transition form factors over the range $Q^2 = 0.1 – 7$ GeV^2 and measure the electro- and photo-production of final states with one and two pseudoscalar mesons.	No	Achieved
2013 M8	Measure flavor-identified q and $\bar{q}$ contributions to the spin of the proton via the longitudinal-spin asymmetry of W production.	No	Achieved
2014 M9	Perform lattice calculations in full QCD of nucleon form factors, low moments of nucleon structure functions and low moments of generalized parton distributions including flavor and spin dependence.	No	Exceeded
2014 M10	Carry out ab initio microscopic studies of the structure and dynamics of light nuclei based on two-nucleon and many-nucleon forces and lattice QCD calculations of hadron interaction mechanisms relevant to the origin of the nucleon-nucleon interaction.	No	Achieved

Milestone Evaluations (draft)
High Temperature/High Density Hadronic Matter

Year	Milestone	Complete?	Status Assessment
2005 M1	Measure J/Ψ production in Au + Au at $\sqrt{s_{NN}}$ = 200 GeV.	Yes	Achieved
2005 M2	Measure flow and spectra of multiply-strange baryons in Au + Au at $\sqrt{s_{NN}}$ = 200 GeV.	Yes	Exceeded
2007 M3	Measure high transverse momentum jet systematics vs. $\sqrt{s_{NN}}$ up to 200 GeV and vs. system size up to Au _ Au.	Yes	Exceeded
2009 M4	Perform realistic three-dimensional numerical simulations to describe the medium and the conditions required by the collective flow measured at RHIC.	No	Achieved
2010 M5	Measure the energy and system size dependence of J/Ψ production over the range of ions and energies available at RHIC.	No	Exceeded (?)
2010 M6	Measure e^+e^- production in the mass range $500 \leq m_{e+e-} \leq$ 1000 MeV/c2 in $\sqrt{s_{NN}}$ = 200 GeV collisions.	No	Achieved
2010 M7	Complete realistic calculations of jet production in a high density medium for comparison with experiment.	No	Achieved
2012 M8	Determine gluon densities at low x in cold nuclei via p + Au or d + Au collisions.	No	Exceeded

Milestone Evaluations (Draft)
Nuclear Structure

Year	Milestone	Complete?	Status Assessment
2006 M1	Measure changes in shell structure and collective modes as a function of neutron and proton number from the proton drip line to moderately neutron-rich nuclei.	Yes	Exceeded
2007 M2	Measure properties of the heaviest elements above Z=100 to constrain and improve theoretical predictions for superheavy elements	Yes	Achieved
2009 M3	Extend spectroscopic information to regions of crucial doubly magic nuclei such as Ni-78	Yes, continuing	Exceeded
2009 M4	Extend the determination of the neutron drip line up to Z of 11.	No	Achieved
2010 M5	Complete initial measurements with the high resolving power tracking array, GRETINA, for sensitive studies of structural evolution and collective modes in nuclei	No, need to delay	Not Fully Achieved
2013 M6	Carry out microscopic calculations of medium mass nuclei with realistic interactions, develop a realistic nuclear energy density functional for heavy nuclei, and explore the description of many-body symmetries and collective modes, and their relationship to effective forces	No	Exceeded

Milestone Evaluations (Draft)
Nuclear Astrophysics

Year	Milestone	Complete?	Status Assessment
2007 M1	Measure transfer reactions on r-process nuclei near the N=50 and N=82 closed shells	Yes	Achieved
2009 M2	Measure properties of and reactions on selected proton-rich nuclei in the rp-process to determine radionuclide production in novae and the light output and neutron star crust composition synthesized in X-ray bursts	Yes	Exceeded
2009 M3	Perform three-dimensional studies of flame propagation in white dwarfs during Type Ia supernova	Nearly	Exceeded
2010 M4	Reduce uncertainties of the most crucial stellar evolution nuclear reactions (e.g. 12C(α,γ)16-O) by a factor of two, and others (e.g. the MgAl cycle) to limits imposed by accelerators and detectors	No	Achieved
2011 M5	Measure neutron capture reactions, including radioactive s-process branch-point nuclei, to constrain s-process isotopic abundances	No	Achieved
2012 M6	Measure masses, lifetimes, spectroscopic strengths, and decay properties of selected neutron-rich nuclei in the supernova r-process, and reactions to predict radionuclide production in supernovae	No	Exceeded
2013 M7	Perform realistic multidimensional simulations of core collapse supernovae	No	Achieved
2013 M8	Perform simulations of neutron star structure and evolution using benchmark microphysical calculations of the composition, equation of state, and bulk properties of dense matter	No	Achieved

Milestone Evaluations (Draft)
Neutrinos, Neutrino Astrophysics and Fundamental Interactions

Year	Milestone	Complete?	Status Assessment
2007 M1	Measure solar boron-8 neutrinos with neutral current detectors	Yes	Exceeded
2008 M2	Collect first data in an experiment which has the potential to observe beryllium-7 solar neutrinos	Yes	Exceeded
2008 M3	Initiate an experimental program at the SNS fundamental physics beam line	No	Achieved
2010 M4	Make factor of 5 improvements in measurements of neutron and nuclear beta-decay to constrain physics beyond the standard model	No	Not Fully Achieved
2010 M5	Make factor of 5 improvement in theoretical uncertainties for testing the Standard Model via low energy electroweak observables	Yes	Exceeded
2011 M6	Improve the sensitivity of the direct neutrino mass measurements to 0.35 eV	No	Achieved
2012 M7	Extend the sensitivity of searches for neutrinoless double-beta decay in selected nuclei by a factor of ten in lifetime	No	Not Fully Achieved
2012 M8	Perform independent measurements of parity violation in few-body systems to constrain the non-leptonic weak interaction	No	Achieved
2012 M9	Obtain results from new high-sensitivity searches for atomic electric dipole moments	No	Achieved

Moving to Performance Measures

Hadronic Physics Performance Measures

- **Definition of "Excellent" – 1) Research leads to quark flavor dependence of nucleon form factors and structure functions being measured; 2) hadron states described with QCD over wide ranges of distance and energy; 3) two-body and three-body nucleon-nucleon interactions expressed in a QCD basis; 4) precision measurements of nucleon spin performed.**
- **Definition of "Good" – 1) Research leads to quark and gluon contributions to the nucleon's spatial structure and spin being measured; 2) theoretical tools for hadron structure being developed and tested; 3) data show how simple nuclei can be described at a nucleon or quark-substructure level for different spatial resolution of the data.**
- **Definition of "Fair" – Supported research leads to modest outputs in only two of the three goals described in the "Good" rating.**
- **Definition of "Poor" – Supported research leads to modest outputs in only one of the three goals described in the "Good" rating**

High Temperature and High Density Hadronic Matter Performance Measures

- **Definition of "Excellent" – 1) The existence of a deconfined, thermalized medium is determined; 2) its properties such as temperature history, equation of state, energy and color transport (via jets), and screening (via heavy quark production) are characterized.**
- **Definition of "Good" – 1) The existence of hot, high-density matter is established; 2) some of its properties (e.g., its initial temperature via the photon spectrum) measured; 3) confinement properties, and energy transport (via jets) are explored.**
- **Definition of "Fair" – Supported research leads to modest outputs in only two of the three goals described in the "Good" rating.**
- **Definition of "Poor" – Supported research leads to modest outputs in only one of the three goals described in the "Good" rating**

Nuclear Structure and Nuclear Astrophysics Performance Measures

- **Definition of "Excellent" - 1) Extensive measurements on stable and exotic nuclei and the drip lines are performed; 2) their structure is established and the isospin dependence of effective interactions studied; 3) new nuclei with neutron skins are observed and studied; 4) reactions for several astrophysical processes, including some r-process nuclei, are measured.**
- **Definition of "Good" - 1) Properties of nuclei and reactions near and far from stability are measured allowing study of effective interactions, collective behavior, and structural evolution; 2) new weakly bound nuclei are observed and the limits of binding explored; 3) some reactions of stellar interest are measured.**
- **Definition of "Fair" – Supported research leads to modest outputs in only two of the three goals described in the "Good" rating.**
- **Definition of "Poor" – Supported research leads to modest outputs in only one of the three goals described in the "Good" rating**

Neutrinos, Neutrino Astrophysics and Fundamental Interactions Performance Measures

- **Definition of "Excellent" - 1) Double beta-decay lifetime limits are extended 10-fold or more; 2) R&D completed demonstrating if precision pp solar experiment is possible; 3) played key roles in low-energy neutrino experiments and beta-decay probing cosmologically interesting neutrino masses.**
- **Definition of "Good" - 1) Double beta-decay lifetime limits extended; 2) participated in low-energy neutrino experiments and beta-decay probing cosmologically relevant neutrino masses; 3) parameters for quark mixing for nuclear beta-decay quantified.**
- **Definition of "Fair" – Supported research leads to modest outputs in only two of the three goals described in the "Good" rating.**
- **Definition of "Poor" – Supported research leads to modest outputs in only one of the three goals described in the "Good" rating.**

Grading Scale for Progress towards accomplishing Performance Measures

- **Excellent – On track to fully achieve Performance Measure, either earlier than anticipated or with additional, related research on the topic completed, or with progress (and/or incremental studies planned that can be completed in time) such that we are confident that the issues will be regarded as settled definitively.**
- **Good – On track to achieve Performance Measure as anticipated, but not likely to have made substantive additional progress.**
- **Fair – Achieving the Performance Measure to the "good" level on the timescale planned is at risk without an increased effort (Note: if the scientific results themselves rule out achieving a milestone – e.g. you don't find new examples of X because Nature hasn't any, then we consider the Performance Measure 'achieved', assuming the experiments/calculations were done.)**
- **Poor – Achieving the Performance Measure to the "good" level on the timescale planned is not likely without substantially increased effort.**

Linking of Milestones to Performance Measures

- **For example: High Temperature, High Density Hadronic Matter**
  - **1) The existence of a deconfined, thermalized medium is determined (from "Excellent") - or - 1) The existence of hot, high-density matter is established (from "Good")**
    - **Relevant milestones**
      - **2005 J/Ψ, 2010 energy/system size for J/Ψ**
      - **2005 flow for multiple strange baryons**
      - **2009 3-D numerical simulations of medium**
  - **2) its properties such as temperature history, equation of state, energy and color transport (via jets), and screening (via heavy quark production) are characterized (from "Excellent") - or - some of its properties (e.g., its initial temperature via the photon spectrum) measured (from "Good")**
      - **2007 jet production; 2010 theory of jet production; 2014 jet production and jet-photon correlations**
      - **2010 e+e- continuum**
      - **2012 gluon density at low-x**
      - **2012 fluctuation studies for critical point**
      - **2016 spectra for tagged heavy flavor**
      - **2018 direct, virtual photon production**
  - **3) confinement properties, and energy transport (via jets) are explored (from "Good")**

Summary Evaluations – I

- **All four areas making at least "Good" progress**
- **In discussion about Good vs Excellent in progress – has to be some aspect of going beyond what is called out in the Performance Measures, which are already demanding**
- **Conclusion in three of four areas is that if present funding trends can be at least maintained, then progress level will be maintained, possibly improved**
- **Conclusion in three of four areas is that if present funding trends can be at least maintained, then by 2015 the performance level reached will correspond to the "Excellent" evaluation called out in the Performance Measure descriptions**
- **Fourth area, Fundamental Interactions, has points of concern about reaching Excellent performance level by 2015. These are in part funding timeline (double-beta decay) and in part definition of approach forward for the area (R&D on low-energy precision solar pp neutrinos)**

Summary Evaluations - II

- **No proposed changes to Performance Measures**
- **Four areas of some concern**
  - **Double-beta decay**
  - **R&D on precision solar pp neutrino experiment (charged-current and/or neutral current)**
  - **Observation of new nuclei with neutron skins**
  - **Deconfinement signal for RHI physics**

Arithmetic Average of Milestone Evaluations

- **Using a scale 4/3/2/1 for E/A/NFA/NSP**

- **Hadronic Physics – 3.1**
- **High Temperature,High Density Hadronic Matter 3.5**
- **Nuclear Structure and Astrophysics – 3.3**
- **Neutrinos, Neutrino Astrophysics, Fundamental Interactions – 3.1**

- **Thinking to include this as a consistency check with progress evaluations**

Plan to Proceed

- **Discussion with representatives of fields**
  - **Ongoing and/or starting**
  - **10-20 in each area**
- **Specific ratings progress towards of performance measures**
- **Finish filling in report outline, editing of milestone evaluations**

- **First draft of report …**
  - **Milestone evaluations in appendix**
  - **Summary of milestones and performance measures, and proposed new milestones, in main body of text**

Extras

Evaluating Mid-Term Progress

- **Need to document what was achieved with respect to the milestones for 2005-2007**
  - **Several sources evaluating research output against the 2003 list of milestones already exist**
    - **LRP input and Town Meeting input**
    - **Program reviews of Lab programs (RHI 2004, Theory 2005, Medium Energy 2006, Low Energy 2007)**
    - **Annual S&T reviews of DOE facilities, NSF reviews and grant submissions**
  - **We should be able to provide sample references where we claim we have fully met a milestone**
- **Several future milestones have been partially met**
  - **Provide documentation of this with sample references**
  - **Note opportunities for further work, with attention to work addressing incomplete aspects of performance measures**
- **Take into account any changes in landscape since 2003 (e.g. RHIC is dealing with a fluid, DUSEL site chosen, progress towards program laid out in APS multi-divisional study on neutrinos, JLab 12-GeV upgrade progress)**

Points We Might Consider in Updating Performance Measures (Specific Example on High Temperature, High Density Hadronic Matter)

- Not much explicit mention of flow, of heavy-quark thermalization, of evidence for strongly-coupled fluid
- Jets noted from the predicted view of "jet-quenching" but not possible existence of a Mach cone shock wave
- Planned RHIC program (FY10-12 ??) to search for the critical point is new
- Program at LHC for detailed study of jet fragmentation and effects of very high gluon density is new
- No obvious discussion of very dense assemblage of gluons – color glass condensate, although my reading of the LRP is that a dedicated e-A machine for such work is outside the timeframe of this revision of the performance measures