**Closeout Report**

on the

*Department of Energy*
*Committee Report*

on the

Facility Operations Review

of the

# Relativistic Heavy Ion Collider (RHIC)

February 7, 2002

DOE F 1325.8
(08-93)

United States Government **Department of Energy**

# memorandum

DATE: November 28, 2001

REPLY TO ATTN OF: Office of Science

SUBJECT: Operations Reviews of the CEBAF and RHIC Facilities

TO: Daniel R. Lehman, Director, Construction management Support Division, SC-81

The Nuclear Physics program supports the operations of two major national user facilities: the Continuous Electron Beam Accelerator Facility (CEBAF) at Thomas Jefferson National Accelerator Facility (TJNAF) and the Relativistic Heavy Ion Collider (RHIC) facility at Brookhaven National Laboratory (BNL). These facilities are supported to develop and provide capabilities that can be utilized to carry out world-class research programs.

This memorandum is to request that you organize and conduct reviews of the CEBAF and RHIC facilities to evaluate present performance and cost of operations, and what funding is needed to effectively support their research mission. In order to do this, your review committee should examine all the TJNAF/CEBAF and BNL/RHIC activities associated with facility operations supported by the Nuclear Physics program, determine the real cost (especially manpower) that is being incurred by Nuclear Physics for each activity, advise whether these activities are required and in the best interest of the Nuclear Physics program, and explore options of reducing funding for these facilities with an evaluation of the associated impacts. In particular, it is requested that your review committee:

1. Perform an analysis and evaluation of the present facility operations.
   - 1.1 What is the mission of the facility?
   - 1.2 How are resources currently used (bottoms up analysis) to carry out this mission?
   - 1.3 Are available resources optimized for the most productive program?

2. Evaluate the impacts of different funding levels on the productivity of the facilities.
   - 2.1 What level of facility operations and scientific productivity could be sustained into the outyears with constant effort funding (at the FY 2002 Appropriations level)?
   - 2.2 What benefits, in order of priority, could be realized with incremental funding above this level?

The TJNAF and BNL laboratories have agreed for the reviews to occur in the weeks of January 21st and February 4th, respectively. I have asked Jim Hawkins in the Nuclear Physics Division to be the point-of-contact with your office for this review. Please contact him if you have any questions or if there is any way our office might provide assistance. Again, I wish to thank you for agreeing to chair this review. I would appreciate receiving the committee's report within 60 days of the review.

Signed by

Dennis Kovar
Director
Division of Nuclear Physics

cc:
James Decker, SC-1
Milt Johnson, SC-1
S. Peter Rosen, SC-20
James Turi, SC-80
Mike Holland, DOE/BNL
Jerry Conley, DOE/TJNAF
Christoph Leemann, TJNAF
Peter Paul, BNL
Tom Kirk, BNL

# Department of Energy Operations Review of the Relativistic Heavy Ion Collider
## February 5-7, 2002

**Daniel R. Lehman, DOE, Chairperson**

**Support**

Casey Clark, DOE/SC

**SC1**

**Experimental Program**

* Donald Geesaman, ANL
Peter Barnes, LANL
John Cooper, Fermilab
Barbara Jacak, Stony Brook
[Stanley Kowalski, MIT]

**SC2**

**Accelerator Operations**

* Rod Gerig, ANL
Stan Ecklund, SLAC
Stanley Kowalski, MIT
John Marriner, Fermilab
[Konrad Gelbke, MSU]

**SC3**

**Management**

* Jay Marx, LBNL
Bruce Chrisman, Fermilab
Lowell Ely, DOE/SC
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**Observers**

Dennis Kovar, DOE/SC
James Hawkins, DOE/SC
Gulshan Rai, DOE/SC
Stephen Steadman, DOE/SC
Jehanne Simon-Gillo, DOE/SC
Brad Tippens, DOE/SC

**LEGEND**

Subcommittee
SC Chairperson
* Part-time Subcommittee Member
[ ] **Count: 15** (excluding observers)

2/6/02:q:sc-81:npopsreview:RHIC:revcmrhic.xls:sh

**Department of Energy Operations Review**
**of the**
**Relativistic Heavy Ion Collider**

**REPORT OUTLINE/WRITING ASSIGNMENTS**

Executive Summary [Charge 1 and 2] ..... Ely

1. Introduction ..... Hawkins
2. Physics and Experimental Program [Charge 1 and 2] .....Geesaman/Subcommittee 1
   - 2.1 Findings
   - 2.2 Comments
   - 2.3 Recommendations
3. Accelerator Operations [Charge 1 and 2] ..... Gerig/Subcommittee 2
4. Environment, Safety and Health ..... Wynveen/Subcommittee 3
5. Funding [Charge 1.2, 1.3, and 2] .....Chrisman/Subcommittee 3
6. Management and Administration [Charge 1 and 2].....Marx/Subcommittee 3

Appendices

A. Charge Memorandum
B. Review Participants
C. Review Agenda
D. Funding Table
E. Management Table

## Physics and Experimental Program Subcommittee

| | |
|---|---|
| **Peter Barnes** | **LANL** |
| **John Cooper** | **FNAL** |
| **Donald Geesaman** | **ANL** |
| **Barbara Jacak** | **SUNY-SB** |

**The successes of the laboratory and users in rapidly extracting exciting physics results from the first RHIC runs have been stunning. These results have firmly placed RHIC at the center of relativistic heavy ion physics in the world. Such a performance required tremendous focus and effort by the users and the laboratory and you came through splendidly.**

**In many ways, your success, which may indeed have stretched everyone to the limit, has demonstrated your strength and resourcefulness. You have just completed a ~30 week colliding-beam run, the projected length of a "typical" full RHIC run. The experiments remain in the installation and commissioning mode and the efficiency is not what one aspires to. However the committee anticipates that as operational procedures become more automated, equipment better understood, and infant fatality issues have been resolved, the present levels of physics and experimental support are basically sufficient for a 30 week run. Indeed the support levels may be able to decrease slightly. We would anticipate the level of engineering effort could be reduced as the major installation projects are completed. We do not see a compelling need for additional technical support manpower in the experimental groups in Physics and Chemistry and in the Experimental Support and Facilities Group in C-AD, although additional manpower can almost always increase the pace of physics results.**

**The RHIC computing facility is the one area that does immediately need increased resources. We recommend the addition of ~3 FTE to ensure that the ever-growing analysis and logging capacities are available to the users in a timely fashion. We also concur with the priority to devote $2M of equipment funds per year to grow the analysis computing capacity at the level required by the expected experimental program.**

**We agree that the number of BNL post-doctoral appointments is relatively low for a research group of this size. However we consider this distribution between permanent staff, post-docs and technical staff to be a management decision. Increasing the fraction of post-doctoral appointments could be a wise reallocation of resources as installation activities wind down.**

**The Instrumentation Division of the laboratory is a unique resource that is providing a valuable mix of focused and long-range R&D for future RHIC detector (and accelerator diagnostics) upgrades. RHIC makes very effective use of Instrumentation Division. Collecting this effort in one location provides the laboratory and RHIC with a broader skill set than RHIC by itself could support. At this laboratory, the funding model for this division makes sense.**

**The committee was concerned that medium- and long-range laboratory plans (examples are significant detector R&D projects or the criteria and decisions for declaring RHIC experiments to be ended) appear to be established without external review. We recommend the laboratory broadly seek focused external viewpoints before committing to these decisions, either by using existing advisory committees or establishing new ones. While laboratory management and the users are working together on many of these issues, external perspective is extremely valuable.**

R. Gerig
J. Marriner
S. Eckland
Stan Kowalski
2/7/2002 10:57 AM

## 3.0 Accelerator Operations

### 3.1 Mission, Resources and Optimization

**Findings:**

- The mission of the Accelerator Division, in support of the Nuclear Physics program, is stated to be:

  "To develop, improve and operate the suite of particle/heavy ion accelerators used to carry out the program of accelerator-based experiments at BNL; support of the experimental program including design, construction and operation of the beam transports to the experiments, plus support of detector and research needs of the experiments; to design and construct new accelerator facilities in support of the BNL and national missions. The C-A Department supports an international user community of over 1500 scientists. The Department performs all these functions in an environmentally responsible and safe manner under a rigorous conduct of operations approach."

- RHIC has just completed its first substantial physics run.

- **Weeks of Operation:** With the FY02 budget, RHIC will operate for physics for 17 weeks. These weeks are already complete and there will be no further operation in FY02. The present shutdown will last through FY02; the critical path item being detector upgrades.

- **Availability:** At the end of the FY01-FY02 run, the availability was 40%. However, we note that RHIC availability is computed in a manner that doesn't permit direct comparison with other facilities. (This is addressed in a recommendation.) Machine studies, machine development, setup, scheduled maintenance, etc., count as downtime in addition to equipment failure. The goal for the next run is ~60%.

- **Machine Performance:** During the FY01-FY02 run, the peak design luminosity goal of $2 \times 10^{26}$ $cm^{-2}$ $s^{-1}$. was met. The peak luminosity was enhanced by lowering $\beta^*$ a factor of two below design. However the design goal of $1 \times 10^9$ ions per bunch was not met (achieved $.75 \times 10^9$) and the integrated luminosity goal of 500 inverse microbarns during the FY01-FY02 run was not met; 80 inverse microbarns were achieved. We found that 50 inverse microbarns/week was the goal and the best week was the last of the run (20 inverse microbarns/week. The goal in the next run remains 50 inverse microbarns/wk, to be achieved by increases in current, luminosity lifetime and availability.

- During the last four weeks of operation RHIC was run with polarized protons.

**Comments:**

- The committee endorses the Accelerator Division mission.

- The RHIC operation has been a major success. While it has not yet met all its design goals, the great progress made, and the design goals seem well within reach. We offer our hearty congratulations.

- The following table is a breakdown of how C-AD operations budget is broken down functionally. It should be noted that this analysis has been done by the lab, and the committee has not changed the numbers, although we have looked and questioned the analysis. We note that sufficient effort is directed at commissioning related availability issues. The R&D is very similar to other laboratories and we consider it reasonable. These numbers are burdened (in K$).

| | | | |
|---|---|---|---|
| Operations; less $6989 for Utilities | | $48882.5 | 67% |
| User Support | $3225.7 | | |
| Accelerator | $43310.3 | | |
| Infrastructure | $2346.5 | | |
| Availability Improvements | | $15867.4 | 22% |
| | | | |
| Increased Capabilities | | $6366.6 | 9% |
| | | | |
| R&D | | $1588.9 | 2% |
| | | $72,7053 | 100% |

BNL is presently attempting to deal with a number of issues associated with **availability**. Some of these are related to the older facilities (e.g., AGS, tandems), and others are associated with the new components of RHIC. The numbers above reflect the emphasis on solving these problems. Additionally, AIP money is directed exclusively at availability-maintainability improvements. We note some of what we consider significant availability upgrades:

- Power supply and quench protection repairs
- Improve ramp control
- Replace AGS sextupole coils
- Collider Helium Storage Addition (AIP)
- Liquid Nitrogen based shut-down cooling system (AIP)
- AGS MMPS generator field supply upgrade (AIP)

Additionally, the Siemens motor generator set is in the process of being repaired after failing shortly following a scheduled overhaul by General Electric. It is not clear whether or not the RHIC program will have to pick up the expense of the present repairs. It is clear that the RHIC program needs the MG set repaired. This could have a large impact on the C-AD budget.

- The **enhancement** activities are primarily directed at removing the fundamental current limitations, improving polarized proton operation and making modifications that allow two species collisions (deuteron on gold). The electron cooling upgrade, which will provide a factor of ten increase in integrated luminosity, remains a low level R&D activity. The items presently being worked on include:

  - Helical dipoles (Magnet Division)

- Solenoids in RHIC to suppress electron cloud instability
- Improvements to low level rf to allow more bunches
- Installation of transverse damper system
- Improvements to ramp controls to allow different species in the two rings

- An additional metric is the ratio of effort to materials and supplies. With the cost of the utilities subtracted, unburdened effort consumes 67% of the budget and procurements account for 33%. This is a typical and reasonable split.

- The committee discussed C-AD staffing levels with the department management. It is noted that the C-AD department FTEs dropped from 346.4 in FY01 to 338.8 in FY02 (including the NP work done by the Magnet Division). It the view of BNL management that this has slowed down accelerator operational improvements. We note that the reduction in FTEs is spread fairly evenly throughout the department. Our view is that the staffing level is lean and consistent with work being efficiently done. Comparisons with other laboratories would lead us to the same conclusion. The RHIC program benefits from the buffer of manpower presently supporting SNS and BAF construction.

- The committee generally finds that the allocation of resources within the C-AD is well optimized and directed at the goals and missions stated. Furthermore we note that the majority of the activities are directed at increasing the number of weeks, increasing availability, or enhancing machine performance. All of these activities will potentially increase the integrated luminosity; the primary accelerator figure of merit. We note that BNL is in the position where increased funding in any of these areas will result in improvements leading to increased luminosity. We concur that a C-AD increase, used efficiently, will lead to increases in integrated luminosity.

**2 Funding Levels –**

**3.2.1 Constant Effort Scenarios**

**Findings:**
The level of funding of C-AD funding has been flat for the past 2 years (5% / year reduction due to inflation), which at this point has left the department very lean. Under a constant effort scenario the laboratory has estimated that only 16 weeks of running per FY is possible. Runs would be combined across FY boundaries resulting in long shutdowns between runs. Most of the reliability improvements would be deferred.

**Comment:**
The first run has identified a number of items requiring upgrade or repair and work has started on them. The next years will likely identify additional items. If funding is not available to address these issues reliability will suffer and actual available time colliding (currently 40%) will remain low. Integrated luminosity increases are anticipated by increasing the bunch intensity and by going to 110 bunches. The latter improvement is not in hand until the vacuum blow up (likely electron cloud) problem is solved, which will cost some amount of money. If after several years, reliability problems are solved, the committee believes more time could be found for running potentially 25 weeks, but would require cuts in staff to pay for power and other consumables related to running.

**3.2.2 Incremental Increase Scenarios**

**Comment:**
The committee feels that an increase of about 10 M$, applied to additional running weeks, and to the availability improvements, and machine enhancements discussed above, would likely lead to an increase in integrated luminosity by at least a factor of two and possibly a factor of eight in the long term (3-5 years).

**Finding:**
The RHIC complex faces many unique maintenance issues because of the reuse of the AGS (where some components date from the 1960's) and RHIC itself, which utilized many components that were purchased in the early 1980's.

> **Comment:**
> We believe that the RHIC management has identified major maintenance issues. Incremental funding discussed above will cover the many outstanding problems, but does not eliminate the possibility of an extended downtime because of aging components in critical systems.

**Finding:**
BNL is considering replacing the Tandem accelerators with an EBIS (electron beam ion source) type injector at a cost of 11.3 M$. The advantage of the EBIS project is that it will improve reliability and reduce maintenance costs. The payback period for the project was estimated by the laboratory to be 2.5 years, including the reduced operational costs and the elimination of the need to replace the aged Tandem control system.

> **Comment:**
> If this project is to proceed, it needs to be endorsed by the BNL management and base-lined. An outside review by technical experts with the participation of DOE should be held to validate the baseline.

**Finding:**
The laboratory has produced a concept for RHIC-II, which results in a ten-fold increase in the luminosity for an approximate cost 6 M$ (R&D) and 54 M$ (construction).

> **Comment:**
> We believe that this concept has great merit and should be pursued vigorously since it offers a huge potential increase in luminosity at a cost that is a small fraction of the facility investment. Because of the large cost, it is important – even at the R&D stage—that this project be developed in conjunction with the detectors, the funding agencies, and the scientific communities in the context of the larger nuclear physics program. We believe that BNL Collider-Accelerator Department is ready to begin the R&D program in FY03 if asked to do so.

### 3.3 Recommendation

1. Consider calculating accelerator availability in a manner that is directly comparable with other facilities that operate in a similar mode.

# RHIC--Environment Safety and Health

Bob Wynveen, ANL

Characteristics

- Standards Based Management System (SBMS) serves as Program Foundation
  - Identifies requirements
  - Establishes expectations
  - Defines practices
  - Implements ISM
- SBMS Building Blocks Related to ES&H
  - Some 20 exist
  - Examples: Conduct of Operations; Hazards Assessment; Operations Procedure Manual; Work Permit Program
  - Goes beyond how work is to be performed and specifies authorization basis
- Line Management is Clearly Responsible
  - $R^2A^2$ for all individuals
  - good evidence of acceptance
  - Accountability experience has an understood and practiced disciplinary component

# RHIC--Environment Safety and Health

- ESH Subject Matter Expertise Presence
  - Broad based
  - Mix of owned, bought, and "free"
  - Operate with objective to serve science in a collegial environment
  - Optimum manpower loading with majority in Collider-Accelerator Department
- Evidence of Strong Desire for Continual Improvement
  - Recognition that perfection has not yet been achieved
  - Good and improving self-assessment program
  - Input to ESH/I Management Plan
  - ISO 14001 registration
  - Inspection program implemented
  - Corrective action tracking system in place
  - Input to performance measure/metrics negotiations
  - Beneficial contributions from established committees
  - User input solicted

# RHIC--Environment Safety and Health

- Performance Results
  - Declining rate of Occurrence Reports
  - Apparent improvement of safety statistics
  - Reduced number of assessment findings requiring corrective action
  - Reduced radiation dose to workers
  - Recognized environmental stewardship improvements
  - Apparent favorable cost, estimated to represent 4.0 - 4.5% of Nuclear Physics Budget
  - Represented potential reduction in DOE local office oversight assessments

Bottom Line

RHIC demonstrates a cost effective and compliant ES&H program based on sound business practice and technical competence.

RHIC funding increases, including that described as optimum, will not require significant additional ES&H resources. "Right Sizing" over the past 2-3 years has served to reach an optimum level of ESHQ support for current operations. Continuing on the path forward should maintain "safety" as a value and not just a priority.

B. Chrisman
L. Ely

The current funding provides for a lean operation with the attendant significant risks of single point failures.

The Constant level of effort budget would probably lead to additional running time in future years as result of the benefits of past efforts to overcome startup problems.

The Committee supports a budget increase of approximately $16M above the FY02 level recognizing another $2M is desirable but requires further justification. (see table below)

**Committee Funding Scenario**

| Item | FY02 ($M) | Committee ($M) |
|---|---|---|
| Accelerator Operations | 72.7 | 82.7 |
| Detector Operations Support | 24.1 | 26.2 * |
| Accelerator Base Equip. | 1.1 | 1.4 |
| Detector Base Facility Equip. | 4.1 | 5.7 |
| Accel. Improv. Projects(AIP) | 2.5 | 2.5 ** |
| Accel. & Detector R&D Prog. | 0.0 | 2.0 *** |
| **Total Facility Base** | **104.5** | **120.5** |
| **Colliding Beams Weeks** | **14** | **30** |
| Studies/Comm. Weeks | 5 | 5 |

At funding levels less than the Committee's recommendation the Committee generally agrees with the distributions the Laboratory provided in the various scenarios. The Committee stresses the importance of current operations in these lower scenarios.

# Management Subcommittee

Jay Marx, LBNL (chair);
Konrad Gelbke Michigan State;
Peter Barnes, Los Alamos;
Lowell Ely, DOE;
Bruce Chrisman, FermiLab;
Robert Wynveen, Argonne

## 1. Overall Management

## Major Findings

The DOE nuclear physics program funds operations of the Relativistic Heavy Ion Collider (RHIC), a flagship national user facility for the nation's basic research community.

The Laboratory described the RHIC mission, the organization and responsibilities of ALD for HENP and the department heads, what each of these department does, the advice mechanisms to ALD, and communications mechanism with the user community which is described in our report.

The laboratory has developed important expertise in a number of areas that are important for conducting a successful science program at RHIC and that are, in addition, an important resource for the Nation's research community. Examples are:

Superconducting magnet technology.

Development of advanced detectors and instrumentation.

Large scale computing and data processing

Comments

1. The RHIC facility and associated research support is well managed. Resources appear to be used effectively to provide for the needs of the ongoing research program. The Laboratory appears to be well poised to carry out the nuclear physics program at RHIC.

2. It is very important that planning for RHIC in the next 5 years be driven by a science-based vision of the measurements that are most important to accomplish and how to optimize the available and requested resources to reach those key goals.

At this review, the major scientific deliverables and the instrumentation and integrated luminosity required to accomplish them were not clearly articulated to the committee by the Laboratory management as a science-driven basis for the requests for incremental funding.

The committee perceives that the Laboratory would benefit from augmenting the intermediate and longer range resource planning for the RHIC program so that the focus of the program on the most critical scientific goals is enhanced. The competition that will be provided by the LHC heavy ion program only sharpens the need to focus the RHIC program and its evolution on the most critical scientific goals.

Recommendation:

The committee recommends that Laboratory management explore mechanisms to increase the science-driven focus on intermediate and long-range resource planning for the RHIC program. Possibilities include an expanding scope for the existing PAC or utilizing a new advisory group to help the Laboratory develop and articulate this focus, or the establishment of the position of a RHIC Scientific Director.

## Summary

The Brookhaven mission in nuclear physics is a key part of the nation's efforts in this important area of basic research. The RHIC facility is a flagship facility in this field and is the core of the nuclear physics program at Brookhaven. Brookhaven management and its users are to be commended for the successful and timely commissioning of the RHIC facility and for the rapid start of a vigorous RHIC physics program.

The RHIC facility and the associated research support is well managed. The Brookhaven staff is providing quality operation of the collider with limited resources, and the RHIC user community (researchers both from within and outside of the Laboratory) is utilizing RHIC to produce first-rate science.

The Laboratory indicates that funding at the FY02 Appropriations level in FY03 and the out-years would result in continued operation at the FY02 level of 19 weeks per year (14 weeks for research) with runs scheduled to bridge the fiscal year boundary with attendant problems from hot weather operations. R&D for accelerator and detectors would be started at the lowest level that can make progress. Funds for accelerator equipment would be held constant and equipment funds for detectors would be reduced.

The committee believes that with constant effort funding at the FY02 base the level of collider and detector operations including computing capabilities, R&D and development of equipment is insufficient to meet the needs of the facility's user community and to achieve the most critical scientific goals for the facility.

The committee was also asked to assess the benefits to the nuclear physics program that would result from an increase of funding for nuclear physics at Brookhaven above the FY02 Appropriations level.