Operating Costs of the Brookhaven Relativistic Heavy-Ion Collider

Nuclear Science Advisory Committee

(R.G.H. Robertson, Chair)

August 14, 1996

On April 29th, 1996, the Nuclear Science Advisory Committee was charged by Dr. Martha A. Krebs, Director, Office of Energy Research, Department of Energy, and by Dr. William C. Harris, Assistant Director, Directorate for Mathematical and Physical Sciences, National Science Foundation, to recommend the appropriate level of steady-state operating costs for the Relativistic Heavy Ion Collider at Brookhaven National Laboratory. The Nuclear Science Advisory Committee (NSAC) appointed a Subcommittee under Dr. J. R. Orr (chair) and Professor Robert P. Redwine (co-chair) to carry out the review, which took place at Brookhaven on July 17-19, 1996. At its meeting on August 9, 1996, NSAC accepted the Subcommittee's report, which is attached. Included with the report is a copy of the charge and a full list of the Subcommittee membership. NSAC's recommendation and a few clarifying comments concerning the report follow.

The Relativistic Heavy-Ion Collider (RHIC), the newest accelerator for conducting basic research in nuclear physics, is the largest such facility ever constructed for nuclear physics research. As described in the recent Long Range Plan for Nuclear Science, RHIC provides a capability unmatched in the world. It will allow very heavy nuclei to be brought into collision at very high energies to create conditions much like those at a time when the universe was only microseconds old. Under these conditions, quarks and gluons may be freed from nuclei to form a new state of matter. RHIC's construction is expected to be completed in the third quarter of FY1999 and steady-state operation achieved within the following year.

The RHIC project from its beginnings in 1986 has carried with it an estimated

cost of approximately $88M (FY99 dollars) to operate, derived from the Conceptual Design Report. The current review is the first in-depth analysis by a committee charged to evaluate the operating costs. The recommended operating budget, starting in FY2000, is $12M higher than the estimate in use until now by the DOE Program Office. The high priority assigned to RHIC by NSAC in formulating its 1996 Long-Range Plan (LRP) for the field remains unchanged.

Notwithstanding its size and ground-breaking capabilities, RHIC remains, in NSAC's view, a remarkably cost-effective facility. Situated at an existing national laboratory, RHIC is supplied with ions from a fully developed injection chain culminating in the Alternating Gradient Synchrotron (AGS), and makes use of an existing tunnel, an existing helium liquefier (the largest in the world), and a superconducting magnet factory with an experienced staff.

As construction of RHIC nears completion, Brookhaven has turned its attention to re-evaluating in detail and reducing the costs of operating the facility. Lab-wide, BNL has made substantial progress in cost reduction and efficiency improvement. Extensive reorganization has streamlined the management structure. Brookhaven has signed a new contract with the New York Power Authority that allows the demand level to increase to 77 MW as needed for the full operation of RHIC at the very favorable rate of $60/MWH.

As a result, NSAC is confident in the analysis of its Subcommittee that this extraordinary new facility can be operated economically, and that it will deliver the exciting science we have been eagerly anticipating for more than a decade.

NSAC expresses its gratitude to its Subcommittee under Dr. Orr and Professor Redwine for their diligent and expert work, and extends its thanks also to Brookhaven National Laboratory for the care with which its proposal was prepared and for hosting the Subcommittee deliberations and the subsequent NSAC meeting.

Recommendation

NSAC enthusiastically supports the exciting physics opportunities at RHIC. RHIC will create unique conditions of matter at very high energy density. Realizing the scientific promise requires full utilization of this facility. Consequently, NSAC recommends approximately 37 weeks of running time per year and $99.8M per year (in FY99 dollars) as the minimum steady-state operating budget for this activity.

Findings

Following their review of the Subcommittee's recommendations, Brookhaven re-evaluated their original estimates and concluded that a total operating budget of $103.3M would be needed for 37 weeks operation. NSAC weighed the information provided by Brookhaven and the Subcommittee's analysis, and voted to endorse the Subcommittee report with the clarification that the $99.8M recommended by the Subcommittee represents the minimum level at which Brookhaven can be expected to operate RHIC. NSAC moreover concludes that:

1. This activity will require, starting in FY2000, a $12M increase over the level projected heretofore by the DOE Nuclear Physics Program Office.

2. The optimal utilization of RHIC for its high-priority research program is approximately 37 weeks per year, with the remainder being devoted to accelerator and detector maintenance and upgrades.

3. Brookhaven National Laboratory has designed a technically advanced and cost-effective accelerator system, but, nevertheless, continues to investigate further design improvements. NSAC encourages that approach, concurring with Brookhaven that significant gains in efficiency and reliability, coupled with reduced manpower costs, might accrue from implementation of a new low-energy injector and control system. Such a program would be an appropriate use of AIP (Accelerator Improvement Project) funds. The level of AIP funding may need to be adjusted in the knowledge of more detailed plans for upgrades, the impact on long-term operation, and the impact on other programs in nuclear physics.

Issues

In formulating its advice to the Agencies, NSAC identified a number of issues that bear on the future operation of the RHIC facility. Some of those issues are also discussed in the Subcommittee report.

1. Estimating the operating costs of such a large and complex facility as RHIC is inevitably accompanied by some uncertainties that are magnified by the 3-year interval between the present review and the expected commissioning date of the accelerator.

   Brookhaven has developed and tested, and DOE has endorsed the use of, an econometric model that was used in the forecasts. Personnel costs are predicted

to escalate at 3.7% per year, and equipment costs at 3.0%. Power costs through June 30, 2000, are defined in the agreement negotiated between BNL and the NY Power Authority. The Subcommittee's evaluation of the staffing levels required to operate RHIC and its detectors are considered by NSAC to be sufficiently accurate, but the costs of that level of effort should be re-evaluated closer to the date of commissioning.

2. Uncertainty surrounds nuclear science budgets and federal science policy at the time RHIC will come into operation. In the event that funding for the field does not keep pace with inflation, NSAC reiterates the view expressed in the LRP that maintaining the balance in the field is of major importance. The operation of the large facilities at optimum beam availability should not come "off the top" but should, if budget conditions force it, be reexamined by NSAC at a later time from the viewpoint of balance of the complete U.S. nuclear science program.

3. It is expected that further program optimization may be possible as RHIC operations get under way. Within the overall funding profile outlined in the Subcommittee report some adjustment of the ratio of personnel to materials, supplies and services costs, or of equipment to operating costs, for example, may be appropriate.

4. Brookhaven staff scientists participate in research, both at Brookhaven and elsewhere, that is not specifically considered in this review, but is the subject of separate, peer-reviewed proposals.

5. A substantial fixed-target (proton) program presently exists at the AGS. The recent "AGS-2000" Workshop, attended by both nuclear and particle physicists, was aimed at identifying the best opportunities for future use of the AGS in the RHIC era. Recognizing the new possibilities made available by the enormous gains in AGS beam intensities, proponents identified specific experiments with compelling physics motivations. It is expected that HEPAP will examine and comment on the merits of the proposed experiments within the next year. Since the HEP directorate is currently sponsoring AGS fixed-target research, and since NSAC did not give the program significant priority in the 1996 LRP, it is the hope of NSAC that responsibility for the support of AGS fixed-target proton research will remain within HEP. Here, support implies the incremental costs of running the external beam line(s) during normal RHIC running, the costs of any new detector(s), and the general-use test beam that is presently used by a variety of

experimentalists from both communities. However, dedicated test-beam running in direct support of the heavy-ion program is considered part of the RHIC base program.

6. The "RHIC Spin" program was identified in the LRP as a potentially exciting area of research, but was assigned a role subordinate to the primary mission of relativistic heavy-ion research. Since then, substantial support for the detector and accelerator modifications has been provided by Japan and has been accepted by DOE. Brookhaven regards the routine provision of polarized protons (instead of unpolarized) as a minor additional effort, a view with which NSAC largely agrees. NSAC expects that RHIC Spin research will be carried out by the two large detector collaborations from the same base program as the relativistic heavy-ion research, with beam time and resources awarded competitively by scientific peer review. As noted by the Subcommittee, operation at $\sqrt{s} = 500$ GeV may not be greatly different in cost from 200 GeV operation, but is not required for the purposes of heavy-ion experiments. Running at that energy would require additional funds or redirection of resources within the base program.

7. The powerful computation capability needed to support the RHIC experiments is the subject of a separate capital equipment proposal now under review. Operating costs for this facility are included in the base program (augmented by user-group support), but may naturally need further review once a decision with respect to the capital component has been made.

8. Operating the massive RHIC detectors will require substantial involvement by university and laboratory users, in a fashion that is now routine in high-energy physics, but which will be a change for many nuclear physicists. NSAC hopes that, in this transition, many of the aspects of training and research that are highly valued in nuclear physics can be preserved. NSAC urges the detector groups, BNL, and the agencies to monitor, and if necessary adjust, the balance between collaboration and BNL support of detector operations.

Report of NSAC Subcommittee on RHIC Operations Costs

August 1996

1. INTRODUCTION

The Nuclear Science Advisory Committee (NSAC) was asked on April 29, 1996 by William Harris, NSF Associate Director for Mathematical and Physical Sciences, and by Martha Krebs, DOE Director of Energy Research, to recommend an appropriate level of funding for RHIC operations after turnon and commissioning of this new facility for nuclear science. The letter from DOE and NSF to Hamish Robertson, the Chairman of NSAC, requesting this review is given in Appendix A. A Subcommittee of NSAC was then appointed by Hamish Robertson to evaluate the costs associated with baseline running of RHIC, as well as those associated with additional options. The membership of the NSAC Subcommittee is given in Appendix B. The Subcommittee findings and recommendations are expected to be used in formulating an NSAC recommendation to DOE and to NSF regarding the appropriate level of steady-state operating funding for RHIC.

The Subcommittee visited Brookhaven National Laboratory July 17-19, 1996 for detailed discussions with BNL management and staff on the range of issues involved in making such an evaluation. The agenda for these discussions is given in Appendix C. We thank the BNL staff for their excellent preparation for this review as well as for their gracious hospitality. The open discussion of various RHIC operating budget scenarios and issues was critical in arriving at a useful estimate of eventual RHIC operating costs.

It was assumed that RHIC operation, with four experiments installed and ready to take data, will begin in 1999. Cost estimates are therefore reported in FY99 dollars.

The Subcommittee focused on two areas: the accelerator complex, including the injectors; and the operation of the experiments, including a proposed dedicated computing facility and test beams. The polarized-proton and AGS fixed-target options were also analyzed at a less-detailed level.

2. EXECUTIVE SUMMARY

A Subcommittee was appointed by the Chairman of NSAC and charged with evaluating the required operating costs for the Relativistic Heavy Ion Collider and its associated detectors. The recommendations of the Subcommittee will help in formulating NSAC recommendations concerning the appropriate level of steady-state operating funding for RHIC. The Subcommittee held extensive discussions with BNL management and staff, including a 2 1/2 day visit to Brookhaven. The Subcommittee findings and recommendations are summarized below. All costs and funding are in FY99$.

Findings and Recommendations

1. The levels of accelerator operations personnel and funding proposed by BNL for a 37 weeks/year scenario (346 FTE's and $65.7M) are very plausible. However, the Subcommittee believes that there are ways to improve efficiencies which will allow the accelerator to run in an acceptable way for 37 weeks a year and which would require fewer personnel and resources. We recommend levels of 295 FTE's and $59.0M.

2. The levels of detector operations personnel and funding proposed by BNL for a 37 weeks/year scenario (114 FTE's and $25.6M) are also very plausible. However, the Subcommittee believes that, largely by maintaining responsibility for operation of the large detector components with the user groups that built them, it will be possible for the BNL part of the detector operations funding to be significantly less than proposed. We recommend levels of 101 FTE's and $23.7M.

3. The levels of Department Office personnel and funding proposed by BNL for a 37 weeks/year scenario are 29 FTE's and $10.5M. The Subcommittee believes that, with the efficiencies and reductions discussed above in place, it will be possible to support and administer the project with significantly fewer personnel and with somewhat less resources. We recommend levels of 23 FTE's and $9.2M.

4. The Subcommittee agrees that some test beam time will likely be necessary, after RHIC is in full operation, to understand and analyze acquired data and to upgrade detector performance in the long term. The required test beams could be provided by the AGS, albeit somewhat expensively. Indeed one can trade off heavy-ion running with RHIC for test-beam running with the AGS. The priority for such test-beam running will best be determined when data-taking has begun, and we recommend that additional funding for test-beam running not be identified now. This activity, when needed, should be supported out of the base program.

5. Although not proposed by BNL at this time, the Subcommittee believes that a significant ongoing detector R&D effort will be necessary. This will likely be at about the $1M/year level and should compete for usual DOE R&D resources.

6. Polarized proton collisions, while not part of the base heavy ion program, are expected to be an important part of the physics program at RHIC. BNL estimates, and the Subcommittee agrees, that the cost per week of running polarized protons will be very close to that of running heavy ions.

7. As BNL points out, it should be possible to run a significant fixed-target program at the AGS in parallel with RHIC heavy ion running, by using the time between the expected two RHIC fills per day. The annual cost (up to about $17M) of such a program is not small and the ultimate interest is uncertain at present, but this option can be kept open for the next few years without serious negative impacts on the RHIC project.

8. Combining the baseline categories above (items 1,2, and 3) as well as Capital Equipment and AIP, BNL proposes 489 FTE's and $109.2M for a 37-weeks/year scenario. The Subcommittee recommends 419 FTE's and $99.8M for the baseline 37 weeks/year scenario. BNL estimates that, if they are staffed for a 37 weeks/year operation and then run some weeks less, the total savings in power and other expendables will be about $0.47M/week. The Subcommittee agrees with this estimate. However, if BNL is staffed for a 27 weeks/year operation, some additional savings are possible. The Subcommittee recommends total base costs of $94.1M for a steady-state 27 weeks/year operation. These costs are provided to NSAC to allow an informed recommendation on the appropriate operating level for RHIC.

3. ACCELERATOR OPERATIONS

The Subcommittee examined the operations estimates provided by BNL in the context of a rather bleak funding picture in which most of the major DOE Labs (including BNL) have recently been forced to lay off personnel and the projected DOE budget for the next several years is not expected to provide relief. Increased efficiency is now demanded; basing estimates on previous experience is not sufficient and the Subcommittee probably judged the estimates more harshly than they would have three, or even two, years ago.

We therefore looked at the different areas searching for organizational changes that would improve efficiency. It was immediately clear that the BNL management has already made great strides in consolidating the AGS and RHIC Divisions, notably in insisting on running the two machines from the same control room. However, the Subcommittee believes that over the next few years this consolidation could and should be continued and estimated the gains to be realized by eliminating independent groups where overlap exists. For example, there are currently several specialized groups, such as for the two injectors, which are responsible for systems which are used for only a few hours per day and sometimes also for only a few weeks per year. Operations personnel should received broad-based training to reduce the required number of individual specialists.

Looking at specific numbers of personnel, the Subcommittee found that Management (5), Operations (25), and Controls (41) were about right. For steady-state operation of the machines, when construction and initial commissioning are complete, we believe that 20 accelerator physicists are too many and recommend a reduction to 13. The combined injector areas was one arena where integration should lead to major reductions. The proposed Source group of 6, Tandem group of 11 and Linac group of 9 for a total of 26 should be reduced to 13, a reduction of 13. The combined number of staff in Cryogenics (proposed 29), Electrical (proposed 54), Mechanical (proposed 75) and magnet repair (proposed 30) for a proposed total of 188 should be reduced to 160, a reduction of 28. This could be achieved by exchange of staff between groups to cover peak demand, and by encouraging cross-training where feasible. In the same spirit of exchange of staff, the proposed RF group of 22 should be reduced to 20, a reduction of 2, and the proposed Instrumentation group should be reduced by 1 to 18.

These cuts lead to a total reduction from the proposed staffing levels of the Accelerator Facilities Division and Magnet Section of 346 (316 + 30) to a level of 295.

The Subcommittee made no cuts to the R&D, Capital and Accelerator Improvement budgets as we strongly believe that the personnel cuts that we recommend can only be achieved if AIP funds are devoted not only to improving performance, but also to improving efficiency. This aggressive program of improving efficiency needs to be pursued now in order to realize the personnel

savings in the steady-state condition.

The present injection schemes used to fill the Booster feature some systems which are antiquated, manpower intensive, and expensive to maintain if they are to satisfy only the needs of RHIC. The Subcommittee recommends that high priority be given early in the operating phase to identify alternate schemes which could be implemented with AIP or other capital funds and which would be overall cost-effective when amortized over the many years of proposed operation.

One key driver in the Magnet Section costs is the rate of failure of the superconducting magnets, which is of course unknown at present. BNL's proposal seems appropriately conservative on this score, but experience may show a failure rate less than what is planned for. This issue should be revisited after a few years of RHIC operation.

4. HEAVY-ION EXPERIMENTAL OPERATIONS

The initial RHIC heavy-ion program will be carried out using two large detectors, PHENIX and STAR, and two smaller detectors, PHOBOS and BRAHMS. The costs which were presented and analyzed in detail are for a yearly program of 37 weeks of heavy ion operation (including on and off-line computing), after the expected period of commissioning. No research FTE's, detector upgrades, or detector R&D are included in these costs.

RHIC detector operations at BNL are expected to consist of three components: an experimental facility support division (47.5 FTE's proposed by BNL) which will provide basic infrastructure support, centrally managed pooled resources, and which will be closely tied to accelerator operations; a number of detector operations groups (56.5 FTE's proposed by BNL) which will provide detector-specific technical support and maintenance and which will be closely tied to the experimental research program; and a RHIC computing facility which will be a centrally-managed pooled resource dedicated to the data recording and analysis requirements of RHIC experiments. For this last component BNL proposes 34 FTE's, of whom 18 FTE's would be funded by experimental operations. The proposed total budget for detector operation including power is $23.5M annually plus $2.2M annually of capital equipment.

The Subcommittee considers the staffing levels for the computer center (at least as currently envisioned) to be appropriate. The professional/technical support requested is very close to the appropriate level, as detailed below. We believe that the proposed total size of the resident core operations groups for the large detectors is appropriate, but recommend that a smaller fraction of this group be supported by operations funds at BNL. Having BNL staff responsible for operational support may provide modestly increased availability to the nuclear physics community, but will necessarily direct resources to the Laboratory from the nuclear physics community at large.

The Subcommittee recommends a reduction in the number of proposed personnel devoted to experimental operations of 13 FTE's. Specific areas that should be looked at are the numbers of mechanical technicians assigned exclusively to shift technical support and the number of Ph.D. FTE's supported by the RHIC operating budget.

The Subcommittee supports the expressed need for shift technical support to provide continuous monitoring of experimental areas, quick response to alarms, fast repairs, and routine maintenance chores. However, we believe that these functions could be provided during the day shift by some of the other technicians assigned as experimental area technical support, thus saving 3 FTE's.

The Subcommittee further recommends that BNL personnel not take on technical responsibilities for systems they did not build. User groups should retain responsibility for their subsystems and provide operational support for those subsystems throughout the period of operations. The MOU's of these groups should be modified to reflect these responsibilities. University groups should realize that if BNL personnel take major responsibility for these functions, resources will not be available to fund university manpower. The Subcommittee believes that the responsibilities and manpower should remain with the groups that constructed the subsystems. The recommended number of experimental group FTE's supported by the RHIC operating budget represents a minimum to maintain adequate detector efficiency to effectively use the collider.

The requested annual capital equipment funding is $2.2M, of which $1.2M annually is for the RHIC computing facility. This is a minimal amount for an experimental program of this scope. The detectors can probably live with a scenario which has every upgrade specifically requesting new funding. However, it is questionable whether the computing facility can function with this level of capital funding once the computers start to be obsolete. An additional $0.5M annually is expected to be necessary.

No continuing R&D funds were requested for future detector upgrades and/or replacement. An R&D program with annual funding of at least $1M can be expected to be needed. This should come through the usual competition for R&D funds from the DOE Program Office.

5. DEPARTMENT OFFICE

The RHIC Department Office will be responsible for administration and oversight of the RHIC facility. Certain overall costs for RHIC operation, such as space charges, are assigned to this office. BNL proposed a total of 29 FTE's for the Department Office. With the reductions of personnel in the Accelerator Operations and Detector Operations Sections discussed above, we believe it will be

possible to administer and support RHIC operations with significantly fewer personnel. We recommend 23 FTE's for this office.

6. TEST BEAMS

BNL proposed AGS test beam operation of 10 weeks annually. In this scenario, 2 beamlines would operate, primarily for STAR and PHENIX, with smaller experiments moving in and out as needed. The available beams would be protons, heavy ions, and secondary beams of electrons, pions, and kaons. Slow extraction from the AGS would be required. This test beam program was estimated by BNL to cost an additional $2.9M and require an additional 10 FTE's.

The Subcommittee questioned the experimental groups and did not find a strong need for an annual test beam program of 10 weeks. The experimental groups stressed the need for some availability of test beams, and the Subcommittee strongly concurs. Test beam availability for detector performance studies following first data analyses and test beams in support of detector upgrades and eventual new experiments are crucial. Proton, heavy ion, and meson beams will be used, so slow extraction from the AGS will be required. However, a need-driven episodic program, scheduled on an annual basis was found to be more appropriate than the proposed annual 10 weeks. Estimates of the needed run lengths are in the range of 4-6 weeks.

The Subcommittee believes that a significant need for test beam capability will exist. However, it should be on an as-needed basis. No additional funding or dedicated manpower is recommended at this time specifically for test beam operation. This activity, when needed, should be supported out of the base program.

7. POLARIZED PROTON OPERATIONS

The spin physics program at RHIC will use polarized protons and both the PHENIX and STAR detectors. In order to retain polarization throughout the acceleration process a partial Siberian snake has been installed in the AGS and two full snakes will be installed in each RHIC ring. Spin rotators will also be required to obtain longitudinal spin direction at the collision points. Various polarimeters are required to measure the beam polarization.

The luminosity expected for proton-proton collisions decreases from about 2×10^{32} cm^{-2}s^{-1} at $\sqrt{s}$=500 GeV to 3×10^{31} cm^{-2}s^{-1} at $\sqrt{s}$=200 GeV. It is proposed to use polarized beam for all p-p running at $\sqrt{s}$=200 GeV; such p-p collisions will be required in any case as part of the heavy ion program. This polarized proton running will provide information on the parton spin structure using the Drell-Yan process and direct photon production. However, to get reasonable count rates

for $W^{\pm}$ and Z^0 production it is necessary to operate at $\sqrt{s}$=500 GeV; this full energy operation would be supplementary to requirements of the heavy ion program.

The construction and installation of the Siberian snakes, spin rotator, polarimeter and spin flippers in RHIC are funded by RIKEN (Japan) as part of an agreement between RIKEN and BNL. This also provides for a second muon arm for the PHENIX detector. It is also expected that RIKEN will provide about 0.5M$/year as a maintenance contribution. The Subcommittee estimates that the cost of operating the RHIC facility per unit of time for the spin physics program differs little from that for the heavy ion program. There is some small increase in power consumption, an increment of 0.5 MW, for $\sqrt{s}$=200 GeV operation. To retain the polarization option some additional expertise will have to be retained to maintain the polarized source, polarized targets and polarimeters. The Subcommittee estimates that these specialized requirements would add about 4 FTE's. Other requirements for power supplies, controls and cryogenic support are seen to be within the scope of the base program.

The Subcommittee has estimated the optimum average yearly operation of the facility to occur somewhere close to 37 weeks per year. If the p-p collision running at $\sqrt{s}$=200 GeV required for comparison running by the heavy ion program is carried out with polarized beam, this will cover some fraction of the spin physics program. Running at $\sqrt{s}$=500 GeV would require additional funds or a redirection of resources from within the base program.

8. FUTURE AGS FIXED TARGET OPERATION

In steady-state operation of RHIC it will be possible in principle to have a significant amount of fixed target running at the AGS, as the time required for filling RHIC is expected to be only several hours a day. The incremental costs will come from increased power consumption by the AGS plus an amount which depends fairly directly on the number of beam lines operated. Full operation of external beam lines is estimated to cost $17.4M. At this time it is uncertain how much scientific priority will be placed on such a future fixed-target program, and by which communities, so this is clearly not part of the RHIC base program.

The Subcommittee understands that Brookhaven wishes to keep open the option of AGS fixed-target running after the turn-on of RHIC. This should of course be done without negatively impacting either the RHIC schedule or costs.

Decisions, if any, on AGS fixed-target running after RHIC turn-on will be taken in the future. At this time the Subcommittee believes that BNL management is at least roughly correct in its estimates of the cost of such a fixed-target program. The Subcommittee does point out that the effective running time for fixed target experiments will likely be significantly less than 2 RHIC fills/day would indicate, as experience with colliders shows that many fills do not last the

nominal lifetime.

9. PERSONNEL AND FUNDING RECOMMENDATIONS

Table 1 contains the Subcommittee recommendations for personnel and funding levels for baseline RHIC operations. In addition, our recommendations for test beam operation and Detector R&D are shown. It should be emphasized that these recommendations are for 37 weeks of operation in FY99$.

It is important to understand what the corresponding numbers would be for other levels of operation. BNL management estimates (and the Subcommittee agrees) that the derivative in power and other expendables around a 37-week scenario is about $0.47M/week of operation. Therefore, for example, if one staffed for a 37-week operation and then ran only 27 weeks, about $4.7M would be saved. However, it is clear that if one plans on a 27-week operation for a number of years the size and organization of the staff may be different and additional savings may be possible. BNL has evaluated a long term 27-week scenario and estimates that this would require total operating costs of $100.5M. This is to be compared to the BNL estimate of $109.2M for a steady-state 37-week scenario. BNL believes that the cost difference between a 37-week scenario and a 27-week scenario will be considerably less if one accepts the Subcommittee's estimate of $99.8M for 37 weeks. The argument for this is that the staff size will be sufficiently reduced already for 37-weeks such that significant additional cuts in staff would imply unacceptable risk of failure. BNL suggests only savings of power and expendables ($4.7M) would be possible.

The Subcommittee accepts the basic argument put forward by BNL, but believes that some modest additional personnel savings would be possible. We recommend a level of $94.1M for a steady-state 27-week scenario.

The 37-week and 27-week recommendations, along with the power and expendables component alone, should be sufficient for NSAC to understand the operating costs of RHIC in a range of running scenarios.

Table 1

Summary of Personnel and Funding Recommendations for 37-Week Operation

(FY99$)

Category	Proposed by BNL		Recommendation	
	FTE's	$	FTE's	$
Accelerator and Magnets	346	65.7M	295	59.0M
Detectors and Computing	114	25.6M	101	23.7M
Department Office	29	10.5M	23	9.2M
Accelerator R&D		1.0M		1.0M
Accelerator Capital Equipment		1.0M		1.0M
Detector Capital Equipment		2.4M		2.9M
AIP		3.0M		3.0M
Base Total	489	109.2M	419	99.8M
Test beams	10	2.9M	0	0.0M
Detector R&D		0.0M		1.0M

10. CONCLUSIONS

The RHIC program of heavy ion collisions represents an extraordinary opportunity for nuclear science and for the nation. It is critical that RHIC have operating resources sufficient to perform the high priority physics program which we all await with great anticipation. However, it is also true that the community and the funding agencies must be very careful not to unnecessarily crowd out other high-quality efforts in nuclear science in these stringent funding times. It is in this spirit that BNL proposed, and the Subcommittee evaluated, steady-state funding costs for the RHIC base program and additional options. The Subcommittee found that the budgets proposed by BNL were well planned and clearly presented. It is also the case that BNL has made significant progress in reducing certain costs, such as power. To evaluate the BNL budgets the Subcommittee looked in detail at the personnel and resources proposed for the various tasks. To arrive at the best estimate of future operating costs it was necessary to work at this level of detail. However, it should be clear that the optimal number and organization of personnel will be determined in the future by those who have to operate the accelerators and detectors with fixed resources.

The Subcommittee understands that the roughly 10% reduction we recommend from the BNL proposal will entail some additional risk for overall RHIC operations. We believe that this level of risk is appropriate and acceptable, but it does assume that sufficient capital and improvement funds will be available to allow BNL to make efficient use of the reduced manpower recommended. We also assume that the RHIC user community can and will provide dedicated and trained people to assist in the operation of the experimental program.

By providing a detailed evaluation of costs for a steady-state 37 weeks/year operation and a solid estimate of the cost-savings involved in a steady-state 27 weeks/year operation, the Subcommittee believes that this will allow NSAC to understand the base costs of operating RHIC for the amount of time/year deemed appropriate.

Department of Energy
Washington, DC 20585

Professor R. G. Hamish Robertson
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Dear Professor Robertson:

The Relativistic Heavy Ion Collider (RHIC) construction project is scheduled to be completed in June 1999. At that time the initial complement of detectors funded within the project, as well as some components of RHIC additional experimental equipment, as reviewed and recommended by the Nuclear Science Advisory Committee (NSAC), should be ready to begin data acquisition. RHIC will therefore be available for commencing its research program soon after the construction project is complete. The expanded capability of colliding polarized protons, funded by the Japanese Science and Technology Agency, with the opportunity to pursue a RHIC spin physics program should follow shortly thereafter.

It is therefore timely, for its planning, that the Department of Energy (DOE) revisit and update its assessment of RHIC's operating funding requirements. To assist in this important task, NSAC is requested to arrange for a review and analysis of RHIC's operating funding requirements, and to provide a recommendation to DOE and the National Science Foundation on the appropriate level of steady state operating funding for RHIC.

Brookhaven National Laboratory is proposing a RHIC operating funding level which includes all funding required for facility operations; including accelerator operations, operations support for experimental areas and off-line computing, and Accelerator Improvement Project and Capital Equipment funding required for the maintenance of the facility. It is important to examine the operating funding requirements in detail to understand what will be required to take full advantage of the new research opportunities at RHIC. At the same time, the actual RHIC operating level must be determined in the context of the funding limitations that are foreseen in the next few years within the Nuclear Physics program.

Proposed funding for in-house research, Capital Equipment for upgrades of the initial complement of detectors and off-line computer system, and major accelerator upgrades may be presented in addition to the base program. The RHIC facility complex will have the flexibility to provide various capabilities for research in addition to its primary mission of nucleus-nucleus colliding beams; notably, Alternating Gradient Synchrotron proton and heavy ion beams for fixed target programs and colliding polarized proton beams in RHIC. These other research capabilities and their costs should be considered as additions to the base RHIC program and each should be commented on separately within your report. Results of previous reviews and the priorities of the Long Range Plan should be taken into account in your deliberations.

In order to properly prepare for RHIC operating funding needs, the DOE requests NSAC's recommendation on this important issue by August 15, 1996.

Sincerely,

William C. Harris
Assistant Director
Directorate for Mathematical
and Physical Sciences
National Science Foundation

Martha A. Krebs
Director
Office of Energy Research
U.S. Department of Energy

APPENDIX B - SUBCOMMITTEE MEMBERSHIP

Rich Orr (Chairman)
Fermilab - Retired

Robert P. Redwine (Vice-Chairman)
Massachusetts Institute of Technology

John M. Cameron
Indiana University Cyclotron Facility

Andrew Hutton
Thomas Jefferson National Accelerator Facility

Barbara Jacak
Physics Division
Los Alamos National Laboratory

Jerry Nolen
Physics Division
Argonne National Laboratory

Dennis Theriot
Fermilab - Retired

APPENDIX C

NSAC Sub-Panel Review of the RHIC Facility Operations Cost

Collider Center, Bldg. 1005S
BNL

July 17-19, 1996

AGENDA

Wednesday, July 17, 1996
(3rd Floor Conference Room, Collider Center)

8:00 am	Executive Session	
8:30 am	Welcome	N. P. Samios
8:45 am	Overview and Methodology	T. Kirk
9:30 am	Accelerator Facility Operations Mode	M. Harrison
10:30 am	Break	
11:00 am	Tour of the Facility	
12:30 pm	Executive Lunch (4th Floor Conference Room, Collider Center)	
1:30 pm	Accelerator Facility Operations Cost	D. Lowenstein
2:30 pm	Experimental Operations - Overview, Infrastructure & Small Experiments	T. Ludlam
3:30 pm	Break	
4:00 pm	PHENIX Operations	S. Aronson
4:30 pm	STAR Operations	T. Hallman
5:00 pm	RHIC Computing Facility Operations	B. Gibbard
5:30 pm	Summary of the Baseline Operation	S. Ozaki

Thursday, July 18, 1996
(3rd Floor Conference Room, Collider Center)

8:00 am	Executive Session	
8:30 am	Polarized Proton Operations	T. Roser
9:00 am	Test Beams	D. Lowenstein
9:30 am	Fixed Target Physics Using AGS Beams	D. Lowenstein

(cont'd)

Thursday, July 18, 1996 (cont'd)

10:00 am Small Group Discussions:
Accelerator Operations - 4th Floor Conference Room
Detector Operations - 3rd Floor Conference Room
Test Beam & Fixed-Target Ops. - AGS Small Conference Room

12:00pm Executive Lunch
(4th Floor Conference Room, Collider Center)

1:30 pm Small Group Discussions (continued):
Accelerator Operations - 4th Floor Conference Room
Detector Operations - 3rd Floor Conference Room
RHIC Computer Center Operations - 3rd Floor Small Conference Room

5:00 pm Executive Session

6:00 pm Adjourn

Friday, July 19, 1996
(3rd Floor Conference Room, Collider Center)

8:00 am Executive Session/Report Organization

12:00 pm Working Lunch

2:30 pm Closeout

3:30 pm Adjourn