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PHY - ELEMENTARY PARTICLE ACCEL USER (continued)

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TITLE OF PROPOSED PROJECT **The ATLAS Research Program: Empowering U.S. Universities**

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PREPROPOSAL NO., IF APPLICABLE
$ **33,040,651**	**60** months	**01/01/02**	

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New York, NY 10027
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CO-PI/PD				
CO-PI/PD				
CO-PI/PD				
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CERTIFICATION PAGE

Certification for Principal Investigators and Co-Principal Investigators:

I certify to the best of my knowledge that:

(1) the statements herein (excluding scientific hypotheses and scientific opinions) are true and complete, and
(2) the text and graphics herein as well as any accompanying publications or other documents, unless otherwise indicated, are the original work of the signatories or individuals working under their supervision. I agree to accept responsibility for the scientific conduct of the project and to provide the required progress reports if an award is made as a result of this proposal.

I understand that the willful provision of false information or concealing a material fact in this proposal or any other communication submitted to NSF is a criminal offense (U.S.Code, Title 18, Section 1001).

Name (Typed)	Signature	Social Security No.*	Date
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Certification for Authorized Organizational Representative or Individual Applicant:

By signing and submitting this proposal, the individual applicant or the authorized official of the applicant institution is: (1) certifying that statements made herein are true and complete to the best of his/her knowledge; and (2) agreeing to accept the obligation to comply with NSF award terms and conditions if an award is made as a result of this application. Further, the applicant is hereby providing certifications regarding debarment and suspension, drug-free workplace, and lobbying activities (see below), as set forth in Grant Proposal Guide (GPG), NSF 01-2. Willful provision of false information in this application and its supporting documents or in reports required under an ensuring award is a criminal offense (U. S. Code, Title 18, Section 1001).

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COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

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PHY - LARGE HADRON COLLIDER

Summary

The ATLAS detector is currently under construction for operation at the Large Hadron Collider (LHC), with initial data taking scheduled for 2006. Extensive studies show that the LHC should be able to elucidate the mechanism of electroweak symmetry breaking and to study a variety of other topics related to physics at the TeV scale. In particular, a Higgs boson with couplings given by the Standard Model will be observable in several channels over the full range of allowed masses. Its mass and some of its couplings will be determined. If supersymmetry is relevant to electroweak interactions, it will be discovered and the properties of many supersymmetric particles elucidated. Other new physics, such as the existence of massive gauge bosons and extra dimensions can be searched for, extending existing limits by an order of magnitude or more. The physics potential of the LHC is enormous: among currently approved facilities in high energy physics, it uniquely has sufficient energy and luminosity to probe in detail the TeV energy scale relevant to electroweak symmetry breaking.

The NSF is making major contributions to the construction of the ATLAS detector, and is also providing significant support for the initial ATLAS computing and software program. NSF funding has supported construction activities at fourteen U.S. universities to date. These institutions are making important contributions to all of the six detector subsystems in ATLAS, and scientists from these institutions hold leadership positions in numerous technical and managerial roles in the overall experiment. As is customary practice in collaborations, including the international collaborations that the U.S. has participated in, groups have continuing responsibilities for the detector components they have built as the detector is installed in the experimental cavern, and during the commissioning and operation phases. These ongoing responsibilities provide the basis for the detector maintenance, operation and upgrade components of this proposal.

NSF funding is also supporting the initial ramp-up of the U.S. ATLAS Physics and Computing project, with a particular emphasis on establishing Tier 2 regional computing centers as part of an overall hierarchical grid of ATLAS computing centers spread around the world. The Tier 2 centers, a key component of this proposal, will play a powerful role in allowing U.S. universities to fully exploit the potential of the LHC, and will set an important precedent for future collaboration on large-scale, international projects.

NSF-ATLAS groups continue to expand their Education and Outreach programs, with a particular focus on high school teachers and students (closely coordinated with QuarkNet), and on outreach to traditionally under-represented populations. We plan on redoubling our Outreach efforts in the run-up to ATLAS data taking, and describe some ideas for extending our program reach beyond the U.S. in this proposal.

In order for U.S. physicists, especially those at universities, to profit fully from these investments, and to be at the forefront of the physics discoveries that will be made at the LHC, it is vital that the U.S. continue to be a key participant in the Research phase of ATLAS. This proposal describes the four major components of the Research Program foreseen for the five-year period beginning in 2002: Computing, Maintenance and Operations, Detector Upgrades, and Education and Outreach. The total funding request is $33,040,651 (FY02$).

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B	Table of Contents (NSF Form 1359)	1	
C	Project Description (plus Results from Prior NSF Support) (not to exceed 15 pages) **(Exceed only if allowed by a specific program announcement/solicitation or if approved in advance by the appropriate NSF Assistant Director or designee)**	15	
D	References Cited	1	
E	Biographical Sketches (Not to exceed 2 pages each)	1	
F	Budget (NSF Form 1030, plus up to 3 pages of budget justification)	11	
G	Current and Pending Support (NSF Form 1239)	1	
H	Facilities, Equipment and Other Resources (NSF Form 1363)	1	
I	Special Information/Supplementary Documentation	0	
J	Appendix (List below.) **(Include only if allowed by a specific program announcement/ solicitation or if approved in advance by the appropriate NSF Assistant Director or designee)**		
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The ATLAS Research Program: Empowering U.S. Universities

1. Introduction

The Large Hadron Collider (LHC) is currently under construction in the 26.6 km circumference tunnel formerly used by the LEP collider at CERN, in Geneva, Switzerland. Upon its completion early in 2006, it will be the world's highest energy particle accelerator, colliding beams of protons at a center-of-mass energy of 14 TeV, and will be the forefront facility for particle physics well into the next decade. The U.S. is a key participant in the construction of the LHC, and is making major contributions to both the LHC machine and its associated detectors.

The ATLAS detector is one of two large, general-purpose *pp* collider detectors being constructed for the LHC. U.S. groups are making very significant contributions to the ATLAS detector: these groups involve about 250 physicists and engineers from 33 U.S. institutions, with major construction efforts centered at numerous universities across the country. U.S. contributions to ATLAS include front-end electronics and Readout Drivers for pixels and silicon strips; mechanics and modules for the pixel system; silicon strip modules; the barrel Transition Radiation Tracker (TRT); readout electronics for the TRT; the Barrel Cryostat; feedthroughs and readout for the liquid argon calorimeter; the EM section of the forward calorimeters; one extended barrel scintillator tile calorimeter and readout electronics; Monitored Drift Tubes and Cathode Strip Chambers for the endcap muon system plus the readout electronics and alignment; and contributions to the Level 2 triggers.

The U.S. is also making substantial contributions to ATLAS offline computing, which will ensure that U.S. physicists, and particularly those at our universities, are in a position to reap the full rewards of the physics program at the LHC. As an integral part of the international data and computing grid planned for ATLAS, it is anticipated that there will be a Tier-1 and several Tier-2 computing centers located across the U.S., where both simulation and physics data analysis will be performed. These will provide democratic access to data and analysis tools for all U.S. collaborators, regardless of geographical location. There are also major contributions to the ATLAS software from U.S. collaborators, including substantial responsibilities for the overall software architecture, database, and reconstruction and analysis packages.

The physics potential of the LHC is enormous. The internal consistency of the Standard Model requires that at least part of the explanation of masses, the origin of electroweak symmetry breaking, must be found at the TeV scale. The LHC is unique among accelerators currently existing or under construction in that it has sufficient energy and luminosity to study this mass scale in detail. Specifically, detailed simulations confirm that:

- If the minimal Standard Model is correct and the Higgs boson is not discovered previously, it will be found at the LHC.

- If supersymmetry is relevant to the breaking of electroweak symmetry, it will be discovered at the LHC and many details of the particular supersymmetric model will be disentangled.
- If the Higgs sector is that of the minimal supersymmetric model, at least one Higgs decay channel will be seen, no matter what the parameters turn out to be. In many cases, several Higgs bosons or decay channels will be seen.
- If the electroweak symmetry breaking proceeds via some new strong interactions, many resonances and new exotic particles will almost certainly be observed.
- New gauge bosons with masses less than several TeV will be discovered or ruled out.
- Signals for extra dimensions will be revealed if the relevant scale is in the TeV range.

With the prospect of these breakthroughs in our understanding of matter at its most fundamental level, the LHC represents a great opportunity not only for U.S. physicists but for the field of particle physics as a whole. The NSF has made major contributions to the construction of the ATLAS detector, and is also providing crucial support for the initial phase of the U.S. ATLAS Physics and Computing project as it gears up towards ATLAS operation and data taking in 2006. In order for U.S. physicists, especially those at universities, to profit fully from these investments, and to be at the forefront of the physics discoveries that we expect will be made at the LHC, it is vital that the U.S. continue to be a key participant in the Research phase of ATLAS.

This proposal describes the major components of the Research Program foreseen for the five-year period beginning in 2002. A brief summary of the expected physics highlights at the LHC is given, followed by sections devoted to U.S. ATLAS Computing, Maintenance and Operations, and Detector Upgrades. Plans for continuing and expanding our successful Education and Outreach efforts are also described. Finally, our proposal to use the existing NSF-ATLAS Project Office at Columbia as a basis for managing the NSF-funded contributions to the ATLAS Research Program is outlined.

2. Physics at the Large Hadron Collider

The LHC machine will collide beams of protons at a center-of-mass energy of 14 TeV, with a design luminosity of 10^{34} cm^{-2} s^{-1}. An initial "low-luminosity" (10^{33} cm^{-2} s^{-1}) phase of operation is foreseen as the accelerator is commissioned, during which several important "discovery" searches will be possible, as well as an extensive program of Standard Model measurements, such as detailed studies of the top quark. CERN Management has recently initiated a study of possible upgrades to the baseline LHC, to explore the implications of a doubling of the center-of-mass energy and/or an order-of-magnitude increase in the machine luminosity (to 10^{35} cm^{-2} s^{-1}). Either of these options would have a significant impact on the LHC detectors.

The ATLAS detector is shown in Fig. 1. It uses a tracking system employing silicon pixels, silicon strip detectors, and a transition radiation tracker, all contained within a 2 Tesla superconducting solenoid. The charged track resolution is $\Delta p_T/p_T = 20\%$ at $p_T = 500$ GeV. The tracker is surrounded by an electromagnetic calorimeter using a lead-liquid argon accordion design; the EM calorimeter covers $|\eta| < 3$ and has a resolution of $\Delta E/E = 10\%/\sqrt{E}$

$\oplus$ 0.7%. The hadronic calorimeter uses scintillator tiles in the barrel and liquid argon in the endcaps ($|\eta| > 1.5$); its resolution is $\Delta E/E = 50\%/\sqrt{E} \oplus 3\%$. Forward calorimeters cover the region $3 < |\eta| < 5$ with a resolution better than $\Delta E/E = 100\%/\sqrt{E} \oplus 10\%$. Surrounding the calorimeters is the muon system. Muon trajectories are measured using three stations of precision chambers in a spectrometer with bending provided by large air-core toroid magnets. The resulting muon momentum resolution is $\Delta p_T/p_T = 8\%$ at $p_T = 1$ TeV and $\Delta p_T/p_T = 2\%$ at $p_T = 100$ GeV. A complete description of the detector is available elsewhere[1].

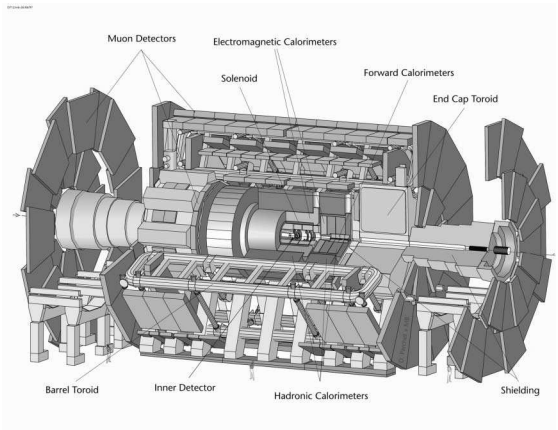

Fig. 1: The ATLAS detector.

The current schedule for the LHC envisions commissioning the machine starting in January 2006, with first collisions foreseen in an April 2006 pilot run. The limited availability of resources as well as technical and schedule constraints have led the ATLAS Collaboration to revise its construction plans for the initial detector. The current plan foresees that the completion of some detector components will be deferred by one to two years during the initial lower luminosity running of the LHC. The choice of the detectors to be staged has been guided by a thorough evaluation of the physics potential and will still allow ATLAS to investigate the major physics topics for the initial physics run at the LHC with a planned integrated luminosity of 3 fb^{-1} by early 2007.

A synopsis of the major physics topics ATLAS will address is given below. A more complete summary can be found at http://www-theory.lbl.gov/~ianh/lhc/.

The Standard Model

The Standard Model (SM) is a very successful description of the interactions of the components of matter at the smallest scales ($\leq 10^{-18}$ m) and highest energies (~ 200 GeV) accessible to current experiments. It is a quantum field theory that describes the interaction of spin-½, point-like fermions, whose interactions are mediated by spin-1 gauge bosons. The fundamental fermions are leptons and quarks, grouped in three generations, with each generation identical except for mass. The origin of this structure, and the breaking of the generational (flavor) symmetry remain a mystery.

In the SM the $SU(2) \times U(1)$ symmetry group describes the electroweak interactions. This symmetry is spontaneously broken by the existence of a (postulated) Higgs field with a non-zero expectation value, leading to massive vector bosons – the $W^{\pm}$ and Z – which mediate the weak interaction; the photon of electromagnetism remains massless. One physical degree of freedom remains in the Higgs sector, a neutral scalar boson H^0, which is presently unobserved. With the recent direct observation of the ν_τ[2], only one particle from the Standard Model has yet to be observed: the Higgs boson. The Higgs is critically important because it holds the key to the generation of W, Z, quark and lepton masses.

Another area in which the Standard Model leaves open questions is the neutrino sector. The minimal SM can only accommodate massless neutrinos and hence no neutrino oscillations. There is now good evidence for such oscillations from measurements of neutrinos produced in the sun and by cosmic ray interactions in the atmosphere[3]. While it is easy to extend the SM to include neutrino masses, understanding their small values seems to require qualitatively new physics.

Beyond the Standard Model

The success of the Standard Model of strong, weak and electromagnetic interactions has drawn increased attention to its limitations. In its simplest version, the model has nineteen parameters[4], seventeen of which are currently determined, with varying accuracies. One of the two remaining parameters is the coefficient θ of a possible CP-violating interaction among gluons in QCD; limits on CP violation in strong interactions imply that it must be very small. The other parameter is associated with the mechanism responsible for the electroweak symmetry breaking. This can be taken to be the mass of the as yet undiscovered Higgs boson, whose couplings are determined once its mass is known. Additional parameters are needed to accommodate neutrino masses and mixings.

The gauge theory part of the SM has been well tested, but there is little direct evidence either for or against the simple Higgs mechanism for electroweak symmetry breaking. The current experimental lower bound on the Higgs mass is 114.1 GeV[5]. If the SM Higgs sector is correct, then precision measurements at the Z and elsewhere can be used to constrain the Higgs mass via its contribution to the measured quantities from higher order quantum corrections to be less than 212 GeV at 95% confidence[6]. As the Higgs mass increases, its self-couplings and its couplings to the W and Z bosons grow. This feature has a very important consequence: either the Higgs boson must have a mass less than about 800 GeV, or the dynamics of WW and ZZ interactions with center of mass energies of order 1 TeV will reveal new structure. It is this argument that sets the energy scale that must be probed to guarantee that an experiment will be able to provide answers to the nature of electroweak symmetry breaking.

The presence of a single elementary scalar boson is unappealing to many physicists. If the theory is part of some more fundamental theory, which has some other larger mass scale, there is a serious "fine tuning" or naturalness problem. Radiative corrections to the Higgs mass result in a value that is driven to the larger scale unless some delicate cancellation is engineered. There are two ways out of this problem which involve new physics at a scale of

order 1 TeV. New strong dynamics could enter that provides the scale of M_W, or new particles could appear so that the larger scale is still possible, but the divergences are canceled on a much smaller scale. It is also possible that there is no higher scale as, for example in models with extra dimensions. In any of the options, Standard Model, new dynamics or cancellations, the energy scale is the same: something must be discovered on the TeV scale.

Supersymmetry is an appealing concept for which there is currently no experimental evidence[7]. It offers the only presently known mechanism for incorporating gravity into the quantum theory of particle interactions, and provides an elegant cancellation mechanism for the divergences provided that at the electroweak scale the theory is supersymmetric. Some supersymmetric models allow for the unification of gauge couplings at a high scale and a consequent reduction of the number of arbitrary parameters. Supersymmetric models postulate the existence of superpartners for all the presently observed particles: squarks, sleptons, gluinos and gauginos. There are also multiple Higgs bosons. There is thus a large spectrum of currently unobserved particles, whose exact masses, couplings and decays are calculable in the theory given certain parameters. Unfortunately these parameters are unknown. Nonetheless, if supersymmetry has anything to do with electroweak symmetry breaking, the masses of the superpartners should be in the region of 100 GeV – 1 TeV.

An example of the strong coupling scenario is "technicolor" or models based on dynamical symmetry breaking. Again, if the mechanism is at all related to electroweak symmetry breaking, we would expect new states in the region 100 GeV – 1 TeV; most models predict a large spectrum. All models predict structure in the WW scattering amplitude at around 1 TeV center-of-mass energy.

There are other possibilities for new physics that are not necessarily related to the scale of electroweak symmetry breaking. There could be new neutral or charged gauge bosons with masses larger than the W and Z; there could be new quarks, charged leptons or massive neutrinos; or quarks and leptons could turn out not to be elementary objects. It is also possible that there are extra space-time dimensions[8,9] that have observable consequences in the TeV energy range. While we have no definitive expectations for the masses of these objects, the LHC and ATLAS must be able to search for them in the available energy range.

ATLAS Physics Goals

The fundamental goal of ATLAS and the LHC is to uncover and explore the physics behind electroweak symmetry breaking. Specifically, ATLAS and the LHC are expected to:

- Discover or exclude the Standard Model Higgs and/or the multiple Higgs bosons of supersymmetry.
- Discover or exclude supersymmetry over the entire theoretically allowed mass range up to a few TeV.
- Discover or exclude new dynamics at the electroweak scale.

The energy range opened up by the LHC also gives us the opportunity to search for other objects:

- Discover or exclude any new electroweak gauge bosons with masses below several TeV.
- Discover or exclude any new quarks or leptons that are kinematically accessible.
- Discover or exclude extra dimensions for which the appropriate mass scale is below several TeV.

Finally, we have the possibility of exploiting the enormous production rates for certain SM particles to conduct the following studies:

- Study the properties of the top quark and set limits on exotic top decays.
- Study of *b*-physics, particularly that of *b*-baryons and B_s mesons.

The extensive studies and simulations performed to arrive at these conclusions are documented in detail elsewhere[1]. Fig. 2 highlights the results of one particularly important analysis, showing not only that the Higgs can be discovered over all of the allowed mass range, but that its mass should be measured with better than 1% accuracy over all of that range.

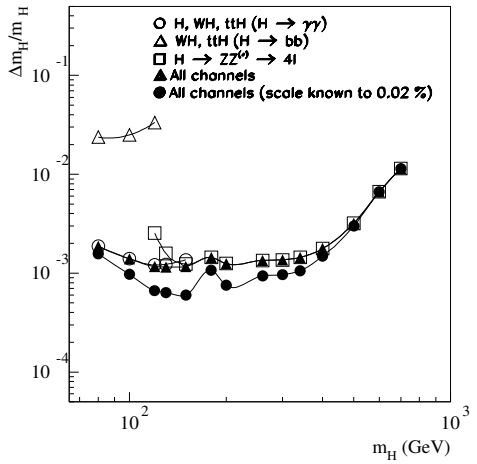

Fig. 2: Expected errors on the Higgs mass in ATLAS.

On the basis of these studies, we believe that the physics potential of the LHC is enormous. Among currently approved projects in high energy physics, it uniquely has sufficient energy and luminosity to probe in detail the TeV energy scale relevant to electroweak symmetry breaking.

3. Physics and Computing

ATLAS will start producing data in 2006 and will reach Petabyte scale data size by 2007. The computing effort for ATLAS far exceeds that of previous high energy physics experiments in the scale of data volume, CPU requirements, complexity of the software

environment, data distribution across a global network, and a widespread geographic distribution of developers and users of software.

The ATLAS computing model is based on a hierarchical network of sites, starting with CERN as the primary (Tier 0) site. The assumption is that all of the raw data from ATLAS will be stored at this Tier 0 site. A U.S. Regional Center, or Tier 1 site, located at Brookhaven National Laboratory, will cache a subset of these data and perform computing tasks as required by both the ATLAS Collaboration and U.S. ATLAS in support of U.S. responsibilities and analysis activities. Beyond the Tier 1 site will be five Tier 2 centers, located at universities across the U.S. Each of these individual centers will have a fraction of the capabilities of the Tier 1 site, but will have a combined CPU power roughly equal to that of the Tier 1 center. The various sites will be linked together by a computational grid, allowing transparent access to users and automatic scheduling of resources, providing U.S. physicists with the optimal environment for efficient analysis of experimental data. This grid framework, with significant concentrations of computing resources at university-based Tier 2 sites, is expected to provide a model for empowering U.S. universities in large-scale, international projects in the future.

The ATLAS analysis software, data storage and database management frameworks must be able to handle this widely distributed large data system. A substantial amount of R&D must be devoted at the outset to establish the grid computing model as a viable operation. The NSF is already supporting advanced IT development to address some of these issues in U.S. ATLAS, most notably through the GriPhyN and iVDGL grid initiatives.

The ATLAS software can be broadly divided into two main categories: general-purpose (or "core") software that is not specific to any one detector subsystem, and detector specific simulation and reconstruction software. Requirements on the software are developed by the international Collaboration, and deliverables negotiated as part of software Memoranda of Understanding. Such agreements serve to formalize national and institutional commitments and ensure that the work is fully integrated into the official ATLAS software. Because of the large scale and long time span of ATLAS, the experiment has committed to developing all software in object-oriented technology, currently using C++ as the programming language. This choice, and experience from recent experiments that have chosen this technology, require that we rely on professional software engineers to design and implement much of the core of the ATLAS software.

In the run up to 2006, significant effort will be needed to produce and analyze simulated data, as well as to implement Mock Data Challenges that will test the full ATLAS computing and software framework. A full schedule of ATLAS computing milestones is available at http://atlassw1.phy.bnl.gov/Planning/usPlanning.html.

For the U.S. ATLAS Physics and Computing project there are two primary goals. The first is to provide the software, computing and support resources to enable U.S. physicists to effectively carry out data analysis and be on the forefront of research and discovery at the LHC. The strategy for achieving this to establish the network of tightly connected computer centers, linked by a common middleware, described above. The second goal is to contribute

to the overall ATLAS Computing efforts to a degree that is both commensurate with the proportionate scale of the U.S. contributions to the detector construction and well matched to the expertise of the U.S. physicists specializing in computing. These contributions are being formalized in the form of software "deliverables" to ATLAS. Further details can be found in the U.S. ATLAS Computing Project Management Plan[10].

There are three components of the U.S. ATLAS Physics and Computing project:

- Physics: Support of event generators, physics simulation, specification of physics aspects of facilities support.
- Software: Development and maintenance of software deliverables to the international ATLAS project, as specified in software agreements and Memoranda of Understanding between CERN, the international ATLAS Collaboration and the U.S. ATLAS Physics and Computing project.
- Facilities: Hardware, networking and software support of U.S. collaborators in data analysis and in computing contributions to ATLAS.

The funding for the Physics and Computing project is derived from a combination of direct Department of Energy (DOE) funds, NSF and DOE R&D funds directed at collaborations of U.S. ATLAS physicists with computer scientists, and direct NSF funding (this proposal). In this proposal, we are requesting funds for each of these three components, to complete the funding needs of the project:

- For the Physics subproject, we are requesting funding for directed effort (1 FTE) to support mock data challenges in the U.S. and the support of simulation interfaces.

- The Software subproject is divided into several categories: core software, detector specific simulation and reconstruction, training, and collaborative tools. In terms of core software, the U.S. has taken on major responsibilities in two main areas: the overall architecture/control framework and the database software. This is as a result of existing expertise among U.S. collaborators as well as the overall need in ATLAS for this crucial component of the software. The U.S. is of course active in many other areas of ATLAS core software. Traditionally, detector specific simulation and reconstruction activities have been carried out by physicists and in the past have not involved the use of Project funds for their support. With modern software methodology, and the increased complexity associated with the scale of the ATLAS Computing project, it is necessary to have a more systematic approach to this, including the use of some software professionals to support the activities of physicists and assist in the maintenance of reconstruction and simulation packages. We are requesting NSF funding to support three (3) software professionals in the areas of data management software and the overall control framework.

- For the Facilities subproject, we are requesting NSF support for activities mostly related to the Tier 2 centers, and the associated computing grid development. (Funding for the BNL Tier 1 center, associated support functions, and contributions to some of the U.S. core computing responsibilities will be sought from the DOE.) It

is anticipated that there will be approximately five ATLAS Tier 2 centers in the U.S., providing hardware and software support functions for U.S. ATLAS institutions in their neighboring regions. Two prototype Tier 2 centers have already been established, with NSF support, at Boston University and Indiana University, and are now beginning the R&D work necessary to validate both the grid computing concept and the ATLAS tiered computing model. Selection of the locations for the final Tier 2 sites is expected to occur in 2003, with funding for these centers beginning in FY04. The specific funding requests are for: completion of funding to deploy grid-related software that has not been fully covered by other proposals (GriPhyN, iVDGL, PPDG), this is mainly targeted at infrastructure at the prototype Tier 2 sites; and a ramp up of Tier 2 centers, with both personnel and hardware, starting in 2004, as part of the preparation for data taking at the LHC. The costing of grid deployment tasks is based on projections of one (1) FTE at each of the prototype Tier 2 sites, and some amount of hardware to support the prototyping efforts. The costing of the Tier 2 site ramp-ups is based on the hierarchical structure with the Tier 1 Regional Center, with the aggregate capacity of the Tier 2's assumed to be roughly equal to that of the Tier 1.

It is likely that the physics output of U.S. ATLAS collaborators will be computing limited during the Research phase of the experiment, and it is vital that adequate priority be given to computing to ensure that U.S. physicists are on the forefront of research and discovery at the LHC. The Tier 2 centers, a key component of this proposal, will play a powerful role in allowing U.S. universities to fully exploit the potential of the LHC, and will set an important precedent for future collaboration on large-scale, international projects.

4. Maintenance and Operations

The U.S. participation in the ATLAS experiment supported by the NSF was structured with two goals in mind: to make the contributions to the construction of the experiment as effective as possible within the resources available, and to use these resources to strengthen the scientific capabilities in the U.S. universities. These goals are compatible because there is in the universities a large intellectual capital developed in past projects to construct major physics experiments, which can be tapped by adding resources to build up teams to produce new detectors for ATLAS. This enables us to make contributions that are extremely valuable to the international ATLAS Collaboration, more valuable than might be expected by looking at the level of the dollars alone. This has been a great opportunity for the universities, since the scientific infrastructure in the universities has not kept pace with the technological opportunities over the last decades. The Construction project is far enough along that we can now report that the universities have risen successfully to the challenge of some really substantial construction projects that many observers might have believed needed the scale of a national laboratory to complete.

Examples, among the thirty university construction efforts, are the collaboration of seven universities to build hundreds of square meters of Monitored Drift Tube tracking detectors for muons with a construction and alignment accuracy of about twenty-five micrometers. This effort included the electronic readout and laser alignment systems, and included no

national laboratories. Another group consisted of four universities with no national lab participation, building a system combining tracking and transition radiation detection, with hundreds of thousands of small "straws" for tracking, together with very advanced radiation-hard electronics. The net effect has been to make an investment on university campuses that has raised the level of the whole physics enterprise in a qualitative manner. Quantitatively, we note that twenty U.S. ATLAS universities are involved in very advanced electronic projects, including the most advanced sub-micron technologies and the most advanced radiation-hard processes. Twenty-one of the universities are carrying out mechanical construction using advanced techniques, often involving large scale construction typically using undergraduate students. These efforts have been used very successfully as an outreach tool with high school students and teachers (see Section 6). One particularly notable example of the effect of investing in university infrastructure is reflected in the recent naming of Hampton University as a Physics Frontier Center (PFC). The Hampton group, funded by the NSF, is playing a key role in producing components for the ATLAS TRT, operating a dedicated clean room facility on the campus. This work, on the energy frontier of fundamental particle physics, is a centerpiece of the Hampton PFC program and will attract new students, postdocs and visiting professors to the university. The expertise and infrastructure that have been accumulated in the U.S. ATLAS institutions during detector construction will be essential as the experiment is installed and commissioned, and begins operation.

The U.S. commitments to the ATLAS Construction project are specified in terms of well-defined deliverables to the experiment, as described in the (Revised) U.S. ATLAS Construction Project Management Plan[11], and references therein. In many cases, the U.S. obligation for these Construction project deliverables concludes when all components have been delivered to CERN, while in others a limited amount of effort is provided for testing at the CERN site or initial installation of the equipment.

According to reasonable and customary practice in collaborations, including the international collaborations that the U.S. has participated in, groups have continuing responsibilities for the detector components they have built as the detector is installed in the experimental cavern, and during the commissioning and operation phases. Three categories of Maintenance and Operation (M&O) activities are included in this proposal - pre-operations, operations and maintenance:

- Pre-operations: Includes final testing (and associated material, electrical, gas, water supplies etc.), calibration, and integration with other detector components or subsystems.
- Operations: Includes activities both during experimental run periods and during shutdowns, for example routine replacement of parts, calibration and monitoring, or implementing improvements to software code, etc.
- Maintenance: Also includes activities both during run periods and shutdowns, for example costs of spare parts, additional tooling/infrastructure required for accessing and repairing detector components, etc. In some instances, particularly for the various radiation-hard ICs needed in ATLAS, spares must be bought early as a "lifetime buy", since it is known that the relevant technologies will become obsolete.

In addition to the M&O costs for specific U.S. deliverables, it is anticipated that each detector subsystem will request that Common Expenses for that subsystem be shared in proportion to the respective contributions to the Construction project. Such Common Expenses might include the costs of contract labor supplied by CERN (e.g. for cabling, plumbing, on-site machining, etc.), consumables (gases, coolant fluids, etc.), and general support of surface assembly equipment and infrastructure.

5. Upgrades

The initial ATLAS detector for the start of LHC operation will be a staged version of the planned full detector. While the staging plan has been carefully optimized to minimize the impact on the initial physics program, there will inevitably be some reduced capabilities. For example, the discovery potential for a Higgs signal in several final states will be degraded such that 20% more LHC running time will be needed to compensate for this loss. This is acceptable for this high priority initial goal, but the degradation for higher mass states like those at the TeV scale suggested by the new theories of extra dimensions will be more serious. This means that upgrades to the detector will be highly productive investments. The upgrades will replace the capabilities lost by staging, but the advance of technology will allow more powerful and more cost effective detectors instead, in many cases, of just replacing originally planned devices. This is much more important taking to account that a vigorous program of machine development is planned for the LHC, leading to a continuous increase of luminosity over time. This is good for the scientific results, but places increasing stress on the detector performance. The detector upgrades will allow ATLAS to exploit fully the high luminosity running of the LHC, and will be chosen to profit from the best new ideas and techniques, with examples given below. This will require substantial R&D, which should start in 2004 in order to be able to carry out the Upgrades in later years.

The initial Inner Detector configuration will defer one of the three pixel layers and its associated read-out electronics as well as the outermost endcap TRT wheels. Full calorimeter coverage is required for the initial LHC physics and is also need mechanically to shield the muon chambers within the ATLAS air-core toroid system. The limited staging that has been implemented for the calorimeters concerns a reduction of the read-out drivers (RODs) and possibly a reduced redundancy in HV power supplies. The cryostat-gap scintillators used for energy corrections in the transition regions between the calorimeter barrel and endcaps will be deferred. For the muon system, some of the precision Monitored Drift Tube (MDT) chambers, including supports and electronics, in the transition region between barrel and endcaps will be staged, and part of the endcap end-wall MDT chambers. Only half of the planned Cathode Strip Chamber layers (mechanics and electronics) will be part of the initial detector. The higher-level trigger and DAQ system will be initially designed to the reduced scope, in a way that can be readily upgraded, and the downstream processor farm will be implemented in an expandable way, starting from a reduced system.

The full potential of the LHC will only be achieved in the high luminosity running of the machine, which is expected to be reached gradually starting in mid-2007. In order to cope with the expected background conditions, the full robustness and redundancy of the ATLAS

detector will be required, according to its design criteria. This means restoring both the pattern recognition capabilities and the resolutions for the large variety of expected (and unexpected) signals. The staged components must therefore be installed in 2007 after the initial run.

The major upgrade activities we foresee in which NSF-supported groups will likely participate include the restoration of the full calorimeter ROD capability, the addition of the cryostat gap scintillators, the addition of approximately 80 muon spectrometer MDT chambers, and the completion of the full Trigger/DAQ system. There may also be a significant U.S. involvement in upgrades of the silicon pixel and strip subsystem.

6. Education and Outreach

Many of the NSF-supported institutions in ATLAS have been active for a number of years in a wide range of Education and Outreach activities. Since its launch in 1999, the NSF- and DOE-funded QuarkNet program has been a natural focus for these diverse Outreach efforts. Of the thirty-four QuarkNet sites that are now active, twenty are U.S. ATLAS institutions and eleven of these are groups that have been funded by the NSF.

QuarkNet provides community high school science teachers with the opportunity to experience particle physics research at first hand. QuarkNet teachers spend their summer "assignments" working alongside physicists, technicians and students on tasks as varied as constructing and testing components for future detectors (such as ATLAS) or analyzing data from running experiments. At many institutions, the teachers also profit from "crash courses" in a wide range of topics in modern physics. One of the goals of the QuarkNet program is that the teachers return to their classrooms and pass on some of the excitement of forefront scientific research to their students, including aspects and examples of modern physics in their curriculum where possible. Feedback from many of the teachers in the program indicates that this has succeeded beyond their most optimistic hopes, and has led to an appreciable number of high school students getting interested, and participating, in the research work at QuarkNet sites around the country.

The first three years of the NSF-ATLAS groups' involvement in QuarkNet have been a clear success, and we expect to build upon and extend our activities as we enter the Research phase of the ATLAS Experiment. One example of a recent initiative to extend the reach of our Education and Outreach activities was the inclusion of four high school teachers from sub-Saharan Africa in our 2001 QuarkNet program. The ATLAS groups at Columbia and at Hampton University invited two teachers each to join their summer workshops, adding a very stimulating international dimension to the QuarkNet experience. Planning for follow-up in Africa is underway, and will initially include visits by U.S. scientists and undergraduates to schools in South Africa, and a Traveling Lab of self-contained physics demonstrations suitable for high school students in South Africa. It is our hope that the QuarkNet program, and others like it, can play a part in bringing the latest advances in scientific research to all parts of the globe.

We place a strong emphasis on targeting diverse populations in our Outreach efforts. We hope that this emphasis will be strengthened by Hampton University's recent designation as a Physics Frontier Center (PFC). The Hampton University PFC is named the Center for the study of the Origin and Structure of Matter (COSM), and has as its physics focus the energy frontier, with ATLAS, and the precision frontier, with experiments at Jefferson Lab. COSM will host workshops in physics, visiting professorships, summer programs for students and postdocs, high school physics activities, and much more. A key component of COSM is the linkage of Hampton to other Historically Black Colleges and Universities (HBCUs) in the U.S. So far, three HBCUs are a part of COSM: Hampton, Norfolk State, and North Carolina A&T State, Universities. The plan is to increase this network to include several other HBCUs over the next several years. The HBCU network will provide a pipeline for students to come to the Hampton University Ph.D. program in particle physics from the other, primarily undergraduate, institutions, and then the new Ph.D.'s from Hampton will be attracted to these HBCUs as faculty members. It is also expected that these new African-American Ph.D. recipients will compete successfully for postdoctoral and faculty positions at majority institutions.

Other activities that have been supported by NSF funding of ATLAS to date include the production of educational videos and CD-ROMs about the experiment, assistance in setting up and constructing demonstration experiments for high school classrooms, and lectures on topical scientific subjects for the general public. We plan to continue and expand such programs in the future.

Aside from our activities aimed at high school populations and the public at large, essentially all of the NSF-ATLAS groups have significant undergraduate and graduate student involvement in their research and detector projects. Experience has shown that this is an invaluable way of giving students some of the research experience and technical training they will need in order to become our future scientists.

7. Project Management

For the Construction phase of ATLAS, the NSF Division of Physics has delegated financial accountability to Columbia University, inclusive of line management authority, responsibility and accountability for overall operations implementation, and contract administration. We are proposing that that Columbia University continue to assume the financial responsibility for NSF funding contributions to the Research Program of ATLAS, and that Columbia continue to serve as the NSF-ATLAS Project Office, working closely with the U.S. ATLAS Project Office at BNL.

Fourteen U.S. ATLAS institutions, including Columbia University, have been supported to date by the NSF under Cooperative Agreement No. PHY 97-22537 for Construction of the ATLAS Detector. The fourteen groups have coordinated their activities during the construction phase of the experiment, with Columbia University assuming responsibility for the work, subcontracting to the other universities.

Project Management for the U.S. ATLAS Construction program has been provided by the U.S. ATLAS Project Manager (Willis), and Project Offices at Columbia University (for the NSF) and Brookhaven National Laboratory (for the DOE). Project oversight has been provided by BNL and by the NSF/DOE Joint Oversight Group.

Columbia has also administered and assumed financial responsibility for some of the initial NSF funding for the U.S. ATLAS Physics and Computing project.

The NSF-ATLAS Project Management role of Columbia University during the Construction phase of the experiment has been functioning efficiently and smoothly. Columbia is currently managing more than 20 subcontracts for the Construction, Computing and Education and Outreach components of the NSF-ATLAS program. The implementation of the U.S. ATLAS Construction Project Management Plan and the U.S. ATLAS Computing Project Management Plan included a number of features that were not very familiar to some of our collaborating institutions. For example the operation under defined Memoranda of Understanding, rather than a Grant, with a necessity of supplying detailed invoices for the subcontracts on a timely basis. On the technical side, we require regular progress reports for each activity in our Work Breakdown Structures with a firm deadline each month. Compliance with these requirements has continued to improve. We plan on implementing a similar framework, including well-defined Memoranda of Understanding, for the Research Program.

The management system now in place at Columbia for NSF-ATLAS maintains close control over expenses and progress tracking, with a minimum burden on the Subcontractors. We have found our organization to be flexible while maintaining a tight managerial control. We expect that our model and our experience will prove valuable for the Research phase of the ATLAS experiment. Further details of the proposed Columbia role, and the overall management of the U.S. ATLAS Research Program, may be found in the (Draft) U.S. ATLAS Research Operations Management Plan[12].

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3. D.E. Groom *et al*. [Particle Data Group Collaboration], Eur. Phys. J. **C15**, 1 (2000).
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5. The LEP Working Group for Higgs Searches, CERN-EP/2001-055.
6. The LEP Electroweak Working Group, CERN-EP/2000-016.
7. For a review see I. Hinchliffe, Ann. Rev. Nucl. and Part. Sci. **36**, 505 (1986).
8. N. Arkadi-Hamed, S. Dimopoulos and G. Dvali, Phys. Lett. **B429**, 263 (1998).
9. L. Randall and R. Sundrum, Phys. Rev. Lett. **83**, 3370 (1999).
10. U.S. ATLAS Computing Project Management Plan, US-ATLAS 00-01.
11. (Revised) U.S. ATLAS Construction Project Management Plan, US-ATLAS 99-20.

12. (Draft) U.S. ATLAS Research Operations Management Plan, US-ATLAS 01-xx, October 2001.

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1. ATLAS Collaboration, ATLAS Detector and Physics Performance Technical Design Report, CERN/LHCC/99-14.
2. K. Kodama *et al*. [DONUT Collaboration], Phys. Lett. **B504**, 218 (2001).
3. D.E. Groom *et al*. [Particle Data Group Collaboration], Eur. Phys. J. **C15**, 1 (2000).
4. R.N. Cahn, LBL-38649 (1996), submitted to Rev. Mod. Phys.
5. The LEP Working Group for Higgs Searches, CERN-EP/2001-055.
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10. U.S. ATLAS Computing Project Management Plan, US-ATLAS 00-01.
11. (Revised) U.S. ATLAS Construction Project Management Plan, US-ATLAS 99-20.
12. (Draft) U.S. ATLAS Research Operations Management Plan, US-ATLAS 01-xx, October 2001.

William J. Willis

Born: September 15, 1932.

1954	B.S. Yale University
1958	Ph.D. Yale University
1958-66	Physicist, Brookhaven National Laboratory
1961-62	Visiting Associate, CERN
1964-68	Associate Professor, Yale University
1968-73	Professor, Yale University
1973-90	Physicist, CERN
1990-	Professor, Columbia University
1993	Elected to American Academy of Arts and Sciences
1993-	Member of Scientific Policy Committee, Russian Ministry of Science
1993-4	Member of Panel on Particle Physics of OECD
1994-	Elected Member of the Executive Committee of the U.S. LHC Collaborators
1994	Assistant Director, Brookhaven National Laboratory
1994-	U.S. Leader of ATLAS at CERN LHC

Selected Publications:

"Bose-Einstein Correlations between Kaons", T. Akesson et al. (AFS Collab.), Phys. Lett. B155, 128 (1985).

"A Comparison of Direct Photon, π^0 and η Production in ppbar and pp Interactions at the CERN ISR", T. Akesson et al. (AFS Collab.), Phys. Lett. B158, 282 (1985).

"A Comparison of Particles Recoiling from High-p_t Direct Photons and π^0 at the ISR", T. Akesson et al. (AFS Collab.), Phys. Scr. 34, 106 (1986).

"Dijet Production Cross-Section and Fragmentation of Jets produced in pp Collisions at $\sqrt{s}$ = 63 GeV", T. Akesson et al. (AFS Collab.), Z. Phys. C30, 27 (1986).

"Direct Photon Plus Away-Side Jet Production in pp Collisions at $\sqrt{s}$ = 63 GeV and a Determination of the Gluon Distribution", T. Akesson et al. (AFS Collab.), Z. Phys. C34, 293 (1987).

"Performance of the Uranium/Plastic Scintillator Calorimeter at the HELIOS Experiment at CERN", T. Akesson et al., Proc. Int. Europhys. Conf. On High Energy Physics, Uppsala, 1987.

"The Transverse Energy Distribution in ^{16}O-Nucleus Collisions at 60 and 200 GeV per Nucleons", HELIOS Collab., Z. Phys. C38, 383 (1988).

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"Identified Pion Interferometry in Heavy Ion Collisions at CERN", Phys. Lett. B302, 510 (1993).

SUMMARY PROPOSAL BUDGET

YEAR 1

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
Columbia University

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
William J Willis

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-mos. CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **William J Willis - none**	**6.00**	**0.00**	**0.00**	$ **0**	$
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	**0.00**	**0.00**	**0.00**	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	**6.00**	**0.00**	**0.00**	**0**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL ASSOCIATES	**0.00**	**0.00**	**0.00**	**0**	
2. (**2**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	**0.00**	**0.00**	**0.00**	**100,213**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**1**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**60,000**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**160,213**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**41,335**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**201,548**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) **FEB electronics maintenance** $ **20,000**					
TOTAL EQUIPMENT				**20,000**	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				**0**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**0**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**2,137,115**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**2,137,115**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**2,358,663**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **Admin (Rate: 63.5000, Base: 75480) (Cont. on Comments Page)**					
TOTAL INDIRECT COSTS (F&A)				**258,737**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**2,617,400**	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPG II.D.7.j.)				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ **2,617,400**	$

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI / PD TYPED NAME & SIGNATURE* **William J Willis**	DATE	FOR NSF USE ONLY INDIRECT COST RATE VERIFICATION
ORG. REP. TYPED NAME & SIGNATURE*	DATE	Date Checked / Date Of Rate Sheet / Initials - ORG

SUMMARY PROPOSAL BUDGET

YEAR 2

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION: **Columbia University**

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR: **William J Willis**

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-mos. CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **William J Willis - none**	**6.00**	**0.00**	**0.00**	$ **0**	$
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	**0.00**	**0.00**	**0.00**	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	**6.00**	**0.00**	**0.00**	**0**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL ASSOCIATES	**0.00**	**0.00**	**0.00**	**0**	
2. (**2**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	**0.00**	**0.00**	**0.00**	**61,318**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**1**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**60,000**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**121,318**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**31,300**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**152,618**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) **FEB electronics maintenance** $ **20,000**					
TOTAL EQUIPMENT				**20,000**	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				**0**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**0**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**3,274,340**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**3,274,340**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**3,446,958**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **Admin (Rate: 63.5000, Base: 75480) (Cont. on Comments Page)**					
TOTAL INDIRECT COSTS (F&A)				**330,792**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**3,777,750**	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPG II.D.7.j.)				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ **3,777,750**	$

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI / PD TYPED NAME & SIGNATURE*	DATE	FOR NSF USE ONLY
William J Willis		INDIRECT COST RATE VERIFICATION
ORG. REP. TYPED NAME & SIGNATURE*	DATE	Date Checked / Date Of Rate Sheet / Initials - ORG

SUMMARY PROPOSAL BUDGET COMMENTS - Year 2

**** I- Indirect Costs**
Comp. Prof. (Rate: 63.5000, Base 48930)
Prof. (Rate: 63.5000, Base 2821)
Subcontracts (Rate: 63.5000, Base 393701)

SUMMARY PROPOSAL BUDGET

YEAR 3

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION: **Columbia University**

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR: **William J Willis**

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-mos. CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **William J Willis - none**	**6.00**	**0.00**	**0.00**	$ **0**	$
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	**0.00**	**0.00**	**0.00**	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	**6.00**	**0.00**	**0.00**	**0**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL ASSOCIATES	**0.00**	**0.00**	**0.00**	**0**	
2. (**5**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	**0.00**	**0.00**	**0.00**	**368,520**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**1**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**60,000**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**428,520**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**110,558**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**539,078**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) **FEB electronics + ROD components** $ **37,000**					
TOTAL EQUIPMENT				**37,000**	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				**0**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**0**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**5,891,990**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**5,891,990**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**6,468,068**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **Admin. (Rate: 63.5000, Base: 75480) (Cont. on Comments Page)**					
TOTAL INDIRECT COSTS (F&A)				**105,333**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**6,573,401**	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPG II.D.7.j.)				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ **6,573,401**	$

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI / PD TYPED NAME & SIGNATURE*: **William J Willis** DATE

ORG. REP. TYPED NAME & SIGNATURE* DATE

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

SUMMARY PROPOSAL BUDGET

YEAR 4

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
Columbia University

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
William J Willis

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-mos. CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **William J Willis - none**	**6.00**	**0.00**	**0.00**	$ **0**	$
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	**0.00**	**0.00**	**0.00**	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	**6.00**	**0.00**	**0.00**	**0**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL ASSOCIATES	**0.00**	**0.00**	**0.00**	**0**	
2. (**6**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	**0.00**	**0.00**	**0.00**	**658,530**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**1**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**60,000**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**718,530**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**185,381**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**903,911**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) **FEB electronics + ROD components** $ **47,000**					
TOTAL EQUIPMENT				**47,000**	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				**0**	
2. FOREIGN				**10,000**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**0**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**9,100,740**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**9,100,740**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**10,061,651**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **Admin. (Rate: 63.5000, Base: 75480) (Cont. on Comments Page)**					
TOTAL INDIRECT COSTS (F&A)				**128,499**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**10,190,150**	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPG II.D.7.j.)				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ **10,190,150**	$

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI / PD TYPED NAME & SIGNATURE* **William J Willis**	DATE	FOR NSF USE ONLY INDIRECT COST RATE VERIFICATION		
ORG. REP. TYPED NAME & SIGNATURE*	DATE	Date Checked	Date Of Rate Sheet	Initials - ORG

SUMMARY PROPOSAL BUDGET COMMENTS - Year 4

**** I- Indirect Costs**
Comp. Prof. (Rate: 63.5000, Base 48930)
Prof. (Rate: 63.5000, Base 77950)

SUMMARY PROPOSAL BUDGET

YEAR 5

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
Columbia University

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
William J Willis

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-mos. CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **William J Willis - none**	**6.00**	**0.00**	**0.00**	$ **0**	$
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	**0.00**	**0.00**	**0.00**	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	**6.00**	**0.00**	**0.00**	**0**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL ASSOCIATES	**0.00**	**0.00**	**0.00**	**0**	
2. (**7**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	**0.00**	**0.00**	**0.00**	**817,737**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**1**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**60,000**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**877,737**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**226,456**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**1,104,193**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) **FEB electronics + ROD components** $ **188,000**					
TOTAL EQUIPMENT				**188,000**	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				**0**	
2. FOREIGN				**20,000**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**0**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**8,428,540**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**8,428,540**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**9,740,733**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **Admin. (Rate: 63.5000, Base: 75480) (Cont. on Comments Page)**					
TOTAL INDIRECT COSTS (F&A)				**141,217**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**9,881,950**	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPG II.D.7.j.)				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ **9,881,950**	$

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI / PD TYPED NAME & SIGNATURE*	DATE	FOR NSF USE ONLY INDIRECT COST RATE VERIFICATION		
William J Willis				
ORG. REP. TYPED NAME & SIGNATURE*	DATE	Date Checked	Date Of Rate Sheet	Initials - ORG

SUMMARY PROPOSAL BUDGET

Cumulative

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
Columbia University

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
William J Willis

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-mos. CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **William J Willis - none**	**30.00**	**0.00**	**0.00**	$ **0**	$
2.					
3.					
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	**0.00**	**0.00**	**0.00**	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	**30.00**	**0.00**	**0.00**	**0**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL ASSOCIATES	**0.00**	**0.00**	**0.00**	**0**	
2. (**22**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	**0.00**	**0.00**	**0.00**	**2,006,318**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**5**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**300,000**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**2,306,318**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**595,030**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**2,901,348**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) $ **312,000**					
TOTAL EQUIPMENT				**312,000**	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				**0**	
2. FOREIGN				**30,000**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**0**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**28,832,725**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**28,832,725**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**32,076,073**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				**964,578**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**33,040,651**	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPG II.D.7.j.)				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$**33,040,651**	$

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI / PD TYPED NAME & SIGNATURE*	DATE	FOR NSF USE ONLY INDIRECT COST RATE VERIFICATION		
William J Willis				
ORG. REP. TYPED NAME & SIGNATURE*	DATE	Date Checked	Date Of Rate Sheet	Initials - ORG

NSF Form 1030 (10/99) Supersedes all previous editions C***SIGNATURES REQUIRED ONLY FOR REVISED BUDGET (GPG III.B)**

Budget Justification

The budget request for Computing, Maintenance and Operations (M&O), Upgrades (including Upgrade R&D), Education and Project Management is shown in the table below. Also shown is the expected NSF funding for the computing grid projects GriPhyN and iVDGL, although these are not part of this Proposal.

	FY02 (k$)	FY03 (k$)	FY04 (k$)	FY05 (k$)	FY06 (k$)	Total (k$)
Computing	**1726**	**1854**	**2793**	**3963**	**4520**	**14856**
Physics	124	150	200	200	200	874
Software	820	844	870	896	925	4355
Tier 2 Manpower:						
Local Staff	542	620	853	697	930	3642
Central Staff				300	465	765
Tier 2 Equipment	240	240	870	1870	2000	5220
M&O and Upgrades	**180**	**933**	**2650**	**4600**	**3750**	**12113**
M&O	180	933	1350	1750	2050	6263
Upgrade R&D and Upgrades			1300	2850	1700	5850
Education and Outreach	100	125	150	175	200	**750**
Project Management	270	373	123	123	123	**1012**
Management Reserve (15%)	341	493	857	1329	1289	**4310**
GRAND TOTAL	**2617**	**3778**	**6573**	**10190**	**9882**	**33041**
Related Computing Projects	**709**	**838**	**856**	**449**	**457**	**3309**
iVDGL	403	532	550	449	457	2391
GriPhyN	139	139	139			417
Grid Telemetry	167	167	167			501

Budget numbers are in FY02k$. A Management Reserve of 15% of the total funding for Computing, Maintenance and Operations, Upgrades, Education and Project Management is included. We note that the proposed U.S. ATLAS contributions to Computing, and M&O and Upgrades, are currently the subject of joint NSF and DOE agency review.

Computing

For the Software budget line, approximately 3-4 FTE software professional support is requested, assuming roughly $170k$/FTE. This effort will support the U.S. core software obligations.

The cost of completing the deployment of grid-related software tasks is based on projections of one FTE at each of the prototype Tier 2 sites, and some amount of hardware to support the prototyping efforts. The hardware typically supports the establishment of routers, commodity processor farms, and disk storage at a level commensurate with a substantial fraction of the anticipated final capacity at the turn on of the LHC.

The costing of the ramp up of the Tier 2 sites is based on the hierarchical structure with the U.S. Tier 1 regional center, wherein the aggregate capacity of the Tier 2's taken together roughly equals the capacity of the Tier 1 site.

Maintenance and Operations (M&O)

CERN has recently asked the LHC experiments to estimate their M&O costs, including estimates for commissioning and installation of the detectors. A Working Group for ATLAS has been established, and has provided a first estimate of overall M&O costs, which have undergone initial scrutiny by a small group representing the CERN Resources Review Board (funding agencies). A draft Memorandum of Understanding for M&O contributions to ATLAS is expected to be finalized in 2002.

U.S. contributions to M&O and Upgrades will focus on the U.S. deliverables for the Construction project. The U.S. plans to contribute to the M&O costs in proportion to the percentage contributions to the subsystem deliverables, as defined in ATLAS document ARN 5-00, Draft 8.1, Sept. 18, 2000. These percentages range from approx. 7% for the U.S. ATLAS silicon and TRT subsystems, to approx. 20% for the U.S. ATLAS liquid argon subsystem. For Commissioning and Integration (C&I) costs, the U.S. plans to support C&I costs for U.S. deliverables only, and believes that this contribution is more than sufficient to be the U.S. share to the experiment.

The M&O and Upgrade costs in this proposal reflect the NSF-ATLAS institutions' responsibilities for detector deliverables in the Construction project. Universities funded by the NSF have played particularly prominent roles in the liquid argon and muon subsystems and these feature prominently in the budget above. For the liquid argon, pre-operations tasks include commissioning and integration of the many U.S. deliverables, contributions to the combined calorimeter test beam program, and the long-term burn-in of the complete Front End crate system. FEB spares and maintenance will be a major continuing commitment. For the muon system, MDT chamber commissioning at CERN begins in 2003, with the subsequent installation of chambers (and associated alignment systems) on their support structures above the pit continuing through 2006. Maintenance tasks include chamber operation, gas systems, electronics, alignment systems, and temperature and magnetic field sensors. For the other subsystems, significant NSF-ATLAS contributions may include IC and module spares for the silicon tracker electronics, spare modules for the TRT, and calibration, installation and maintenance of the Tile calorimeter front end electronics. General maintenance (beam off) and operations (beam on) tasks are included for all subsystems.

Upgrades

The detector upgrades will replace the capabilities lost by staging, but the advance of technology will allow more powerful and cost effective detectors instead of replacing originally planned devices. A substantial R&D effort will be required, which should start in 2004 in order to be ready for the scheduled increases in the LHC luminosity.

NSF-funded universities will play a major role in providing the full complement of precision muon tracking chambers and alignment instrumentation during the period of this proposal, and will also be key players in upgrading the liquid argon ROD system to restore the full functionality of the calorimeter. Both of these items appear in the 2004 budget, continuing through 2006. The cryostat scintillators and fibers for the Tile calorimeter will also be an important upgrade.

In the case of an LHC luminosity upgrade, NSF-ATLAS institutions might be expected to make major contributions to the development of new rad-hard FEBs for the LAr calorimeter, to a replacement inner tracker, and to an upgraded Trigger/DAQ system, among other items.

Education

Based upon the success of our US-ATLAS Education and Outreach efforts during the Construction phase, in conjunction with the expansion of the QuarkNet program, we expect to roughly double our effort and expenditure during the five-year period of the proposal. This funding will support the continuation of programs described in the Project Description of this proposal, as well as new initiatives.

Project Management

We are proposing that Columbia University continue to assume the financial responsibility for NSF funding contributions to the Research program of ATLAS, and that Columbia continue to serve as the NSF-ATLAS Project Office, working closely with the U.S. ATLAS Project Office at BNL.

Based in part on our experience during the Construction phase, we anticipate that of order twelve institutions will receive NSF funds for M&O and Upgrade activities during this proposal period. We propose that Columbia continue to coordinate this work, subcontracting to the other collaborating institutions, building on the framework established in order to manage the NSF-ATLAS Cooperative Agreement for detector construction. For NSF-ATLAS Computing activities, we estimate that roughly eight institutions may receive funding from this proposal, and that there will be a small number of institutions (say, five) receiving funding for Education and Outreach activities. In total, we estimate that Columbia may be administering approximately 25 subcontracts during the Research phase. The current indirect cost rate (ICR) overhead on subcontracts issued by Columbia is $15,875 per subcontract. Assuming 25 subcontracts, the total ICR is estimated to be approximately 397k$. We expect that these subcontracts will mostly be initiated in the first or second year of this proposal period, and have allocated the overhead charges accordingly in our budget table (147k$ in FY02, 250k$ in FY03). We are requesting 1 FTE administrative support to help manage the subcontracts, and maintain financial records. This cost is estimated at 123k$ per year, including fringe and overheads.

Current and Pending Support

(See GPG Section II.D.8 for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: **William Willis**

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **NSF PHY 97-22537 "Construction of the US ATLAS Detector at the LHC"**

Source of Support: **NSF**

Total Award Amount: $ **12,290,000** Total Award Period Covered: **01/01/01 - 12/31/01**

Location of Project: **Columbia University Nevis Laboratories**

Person-Months Per Year Committed to the Project. Cal:**6.00** Acad:**0.00** Sumr: **0.00**

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **NSF PHY 98-13383 "Experimental Particle Physics Research Program at the Columbia University Department Nevis Laboratories"**

Source of Support: **NSF**

Total Award Amount: $ **2,840,000** Total Award Period Covered: **02/01/01 - 01/31/02**

Location of Project: **Columbia University Nevis Laboratories**

Person-Months Per Year Committed to the Project. Cal:**0.00** Acad:**1.50** Sumr: **2.00**

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **NSF PHY 99-07985 "Computing at the LHC"**

Source of Support: **NSF**

Total Award Amount: $ **1,920,000** Total Award Period Covered: **05/01/00 - 04/30/02**

Location of Project: **Columbia University Nevis Laboratories**

Person-Months Per Year Committed to the Project. Cal:**0.00** Acad:**0.00** Sumr: **0.00**

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Summ:

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

FACILITIES, EQUIPMENT & OTHER RESOURCES

FACILITIES: Identify the facilities to be used at each performance site listed and, as appropriate, indicate their capacities, pertinent capabilities, relative proximity, and extent of availability to the project. Use "Other" to describe the facilities at any other performance sites listed and at sites for field studies. USE additional pages as necessary.

Laboratory: **4580 sq. ft. High Bay area with overhead crane and semi-trailer access**
6293 sq. ft. Machine Shop
4565 sq. ft. Electronics Shop

Clinical:

Animal:

Computer: **2025 sq. ft. Computer Facility wiht four offices**
SGI 4-processor Challenge (400 SpecInt)
3 Alpha Workstations
4 Dell Pcs

Office: **17 Research Staff offices (4533 sq. ft.)**
Local HEP journal and preprint library
8 Research Group rooms (4580 sq. ft.)

Other: **Purchasing and Stock Room (3170 sq. ft.)**

MAJOR EQUIPMENT: List the most important items available for this project and, as appropriate identifying the location and pertinent capabilities of each.

Machine Shop/High Bay area:
Large-travel NC Milling Machine
Specialized aluminum welding equipment
High vacuum leak detector equipment

OTHER RESOURCES: Provide any information describing the other resources available for the project. Identify support services such as consultant, secretarial, machine shop, and electronics shop, and the extent to which they will be available for the project. Include an explanation of any consortium/contractual arrangements with other organizations.

Microcircuits Laboratory (funded mainly by the Keck Foundation) (5070 sq. ft.)
IC design, layou and simulation hardware/software
HP IC measuring and testing facility
High precision analog test equipment probe station and VME DAQ system