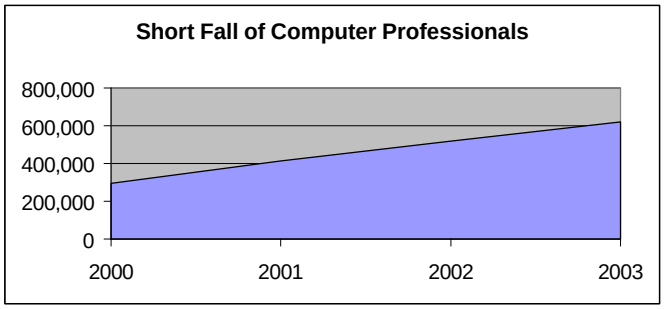
1: Motivation: Workforce, Technology and Education

The continued and growing need for computer professionals is documented in many formal and informal ways. Data from the U.S. Bureau of Labor Statistics suggest the need for a 100% increase in the production of these professionals, and the figure shows this in another way as the expected growth in shortfall [35,38,49]. It is clear that the number of graduates produced by the nation's universities will be insufficient to meet this demand, and we already see an influx of companies hiring non-US citizens who are ready and willing to fill these jobs. Additionally many companies are hiring persons with scientific degrees in other disciplines (math, biology, statistics, etc.) and training them in abbreviated fashion to fill computing jobs. NSF Science Resources Studies, the National Center for Education Statistics and the Commission on Professionals in Science and Technology have documented such trends, and the latter has in particular highlighted the a serious deficiency in the number of minority computing professionals [10]. We suggest that existing universities can only meet this need for computer science graduates by turning to distance education.



It appears that traditional approaches are not adequately addressing these trends and in this proposal we will research novel approaches to computer science education that will both increase the quality of the learning environment and allow the increase of graduating students needed by the nation. The products of the proposed work will be both new computer science curriculum and development and assessment of new technology enhancements for learning. There has been a rapid profusion of commercial training efforts in this arena [12] but we will focus on higher education courses, which have been proven to be more effective pedagogical approach for producing students with lasting knowledge. We have chosen two distinct and important student bodies as testbeds for our curriculum: firstly a network of HBCU's led by project partners JSU and FAMU who have already had substantial success in Internet based curriculum. Secondly, the state of Florida represents one of the fastest growing states with significant large and small computer-based businesses. Here the second major project partner is the FSU Office of Distributed and Distance Learning (ODDL) with institutional responsibility in this area and a new computer science curriculum as a major initial thrust. This testbed reaches in particular non-traditional students and those in the Florida Community College System (FCCS).

Teaching computer science is particularly challenging as the growing student interest is coupled with increasing difficulty in hiring good faculty and the need for constantly updating courses and whole curriculum to maintain relevance in a technology cauldron stirred with Internet time. Our testbeds are set up as institutional networks that naturally allow faculty, mentors and students to participate in the learning process and so increase the pool of qualified teachers. Course content changing with Internet time implies substantially more faculty involvement in the continuing evaluation and upgrading of the curriculum. This accentuates the need for quality learning environments that scale to many more students than a traditional classroom. This naturally suggests Internet-based distance education supported by a hierarchical network of teaching assistants, mentors and faculty. The technology component of our project will research and deploy a mix of academic and commercial capabilities to enable such a learning paradigm.

Several approaches to web-based (distance) education have been developed and applied with some success. These include the largely asynchronous database-linked commercial Blackboard system being deployed by FSU and the synchronous collaboration-based courses delivered over last 3 years between Syracuse (Fox, McCracken) JSU and other HBCU's [37]. Looking to the future, distance education will be the pioneer in the efforts to increase the efficiency of higher education and to adapt curricula to the changing demands of modern society. However, immature technology and historical reasons that are likely to change largely drive current choice between the use of asynchronous and synchronous models.

Synchronous instruction comes with an ongoing high price tag that cannot be reduced due to the human factor (faculty) and his/her limited availability in time. Asynchronous education has a higher up front cost which is a difficulty in a rapidly varying curriculum and where authoring technology is still changing rapidly. We see the needs for unified systems supporting different interactivity models, and further that this choice will be customizable to the individual learner. Indeed five years from now the seemingly oxymoron of providing individualized education in the mass production learning environment of a virtual university should become

reality. The technology component of our proposal will develop a framework that will support the key characteristics of unification of interaction paradigms and the customizability for each learner. This framework must inevitably support a variety of tools coming from a mix of academic and commercial sources. Further, the technology decisions will be structured as relatively short 6-12 month modular projects for the adjustment to a technology and tool environment moving with Internet time.

As we innovate both delivery technology and computer science curriculum, the project is fundamentally centered on its two learning testbeds described in Sec. 2 and the assessment activity of Sec. 3 to evaluate both technology and curriculum. The computer science contributions of this proposal are to both "Education and Workforce" and in research in the distributed system technology to support a virtual university. The latter is described in Sec. 4 while management and budget issues are in Sec. 5 and comments on the team in Sec. 6.

2: HBCU and Florida Testbeds

The project is centered on computer science education in two major testbeds. The largest will be a network of HBCU's starting with our partners JSU and FAMU. An essential idea behind our approach is the scaling of quality educational material by using technology that supports dissemination to many students and simultaneous training of teachers, mentors and assistants. We will implement this by the exchange of material between the participating universities: a concept successfully tested by Syracuse, JSU and Morgan State [3,4]. The next steps in this process include:

1) Identify similarities among curriculum and course content characteristics that allow categorization of courses and places where courses can be shared.
2) Identify candidate course delivery mechanisms.
3) Provide adequate infrastructure at participating colleges/universities.
4) Deliver similar course content with different technologies using flexible multi-source framework of Sec. 4.
5) Evaluate results using the assessment process of Sec. 3. This will lead to an understanding for each of several categories of courses, which technologies/software tools/environments are best suited for course delivery in both distance education and the resident classroom

The HBCU partners in existing programs will seed the network. This includes DoD PET (Programming Environment and Training) partners at ARL, ASC, ERDC and NAVO: Alcorn State University, Central State University, Clark Atlanta University, Grambling State University, Morgan State University, North Carolina A&T University, Southern University, Tennessee State University. The NASA Minority University - Space Interdisciplinary Network (MU-SPIN) Network Resource and Training Sites (NRTS) bring City College of New York (CCNY), Elizabeth City State University, Prairie View A & M University, Morgan State University, South Carolina State University, Tennessee State University, University of Texas at El Paso. The Army High Performance Computing Research Center involves Clark Atlanta University, Howard University, and Florida A & M University. The organization of these partners will be the responsibility of JSU, which has recognized that Web-based distance education technologies offer tremendous potential benefits to the HBCU/MI community, including curricular enhancement, sharing of limited resources, and collaborative teaching/learning. JSU has already developed a university-wide strategic plan for distance education and training which we will leverage in this NSF ITR proposal.

JSU will take responsibility for collaborating with the network partners to ensure that they have an adequate infrastructure to support the innovative course development and delivery. This infrastructure includes 1) suitable physical classroom facilities, 2) a reliable and sufficient connection to the Internet, and 3) on-site human resources. JSU has gained considerable expertise and experience with respect to what is needed, and effective procedures to overcome the barriers to implementation. JSU's role in this project would focus on design, planning, procurement, and installation of required equipment and connections at selected partnership institutions. Also, JSU will facilitate the training of collaborating faculty and staff. A fully equipped, and staffed, teaching and learning laboratory at JSU will allow 1) collaborative course development and 2) cost-effective local and remote instructional training with collaborating schools. Such training and support is essential to the success of this project. We intend to build upon this foundation and develop a national resource for technologies supporting electronic delivery of education and training, which will facilitate inclusion of and broaden the participation of, underrepresented groups in information technology careers. Note we do not intend to supply significant network infrastructure as part of this proposal, as NSF already has in place efforts in this area. There is for example the Educause/NSF PACI EOT Advanced Networking Project with Minority -Serving Institutions (AN-MSI) grant. We hope that membership in our network will encourage universities to upgrade their IT infrastructure, which will of course have far reaching benefits outside our project.

Faculty and staff in the network of universities will develop course content, receive courses from other institutions and deliver courses to partner schools. A result of this process will be:

1) Well-defined principles for course development and delivery.
2) A coalition of HBCU/MI colleges/universities equipped to develop, deliver and receive courses.
3) A large number of faculty, staff, and students who are more IT literate.
4) A large number of students (both students and teaching assistants) better trained for IT careers.

The second network will have some similarities – consisting of Florida community colleges linked to FSU – and is already in place. For this project, we will not actively pursue building the network, as this is the state's responsibility. Rather we will use project curriculum where appropriate and see how the different student demographic and more tightly coupled organization affect the success of our program.

The course material will be primarily aimed at undergraduate computer science students but we will include both middle/high school and graduate level courses where we have success in the past [28]. We will develop (and use pre-existing) interactive material (such as Java applets) and develop common subject specific resources such as quizzes and glossaries. As described in Sec. 4, a major challenge will be to ensure that we have identified the correct places to define standards (in XML). Further we must establish the happy compromise between total freedom in choice of authoring tools and the restrictions imposed by the capabilities of a realistic system framework. For instance, the collaboration and assessment services will support some methodologies (e.g. Java and HTML/XML) better than other specialized authoring formats for which the internal event structure and document object model is either unknown or not in accordance with standards like those of the W3C [52].

3: Assessment Plan

We will assess the effectiveness of technologies, individually and collectively, intrinsically and how they are used, and use the results to continuously improve the essential goal – computer science education for the workforce of the new millennium. Our underlying principle is to provide a flexible learning environment supporting multiple learning styles and allowing dynamic choices to be made by students, faculty, and programs. This assessment theme is very similar to some classical experimental investigations in computer science, for example, in operating systems, where specific algorithms for process management need to be evaluated for effectiveness in the context of real use by real humans. The assessment team will be led by FSU ODDL and FAMU and cover both testbeds.

Research has consistently found little significant difference in learning achievement among various distance learning environments or between distance learning environments and classroom environments [11,45,50]. Further, self-selection by students according to personal learning style needs to be recognized as an important variable. Thus we will assess taking specifically into account the learning style of the students. Our quantitative assessment will be outcomes-based, with three classes of outcomes: *success, efficiency, and satisfaction.*

- *Success outcomes* include learning outcomes, graduation rate, and employment rate.
- *Satisfaction outcomes* include all relevant populations: students (while in a class, after class completion, at program graduation, after x years of postgraduate employment), employers, faculty. We measure satisfaction with learning as well as technology acceptance and usability.
- *Efficiency outcomes* include time invested (by students, faculty, and support team per student credit hour), re-usability of courseware (across institutions as well as over time), and costs of maintenance of technology and courseware.

In two Syracuse Ph.D. theses, Lee and Sen [30,43] have explored the technology needed to track student progress through online material. The capability to monitor and datamine such information is likely to improve as this critical for commercial portals. We will include such assessment techniques in our project as they become useful in practice.

We will supplement the strategies above with a more qualitative assessment thrust, which includes:

- *External peer review:* ODDL is already establishing an external refereeing process for its courses and an external peer assessment process using faculty from peer departments in peer institutions not associated with this project. (This is in addition to, and independent of, the already existing External Advisory Board that has been used to inform ODDL and Computer Science during the setting up of the distance computer science programs for Florida community colleges.) We will expand this process to include both testbeds and

to a broader national community as represented by EOT (Education Outreach and Training) effort of the NSF PACI program and the NSF CILT Learning and Intelligent Systems center [7].

- *Customer feedback*: Using interviews and focus groups from students, faculty, academic programs, and industry to assess customer satisfaction and identify areas for change and improvement.

All of the assessment results will be used in a feedback-improvement loop to continuously improve both the technology and the courseware during and after the project. The availability of useful assessment information and its use for self-improvement, particularly on time scales shorter than a semester, is largely unavailable to standard classroom instruction. Continuous (short and long time scale) self-improvement and opening the process to all possible learning styles simultaneously are two ways in which the new systems can result in better performance over classical systems.

4: Distance Education Technology and Computer Science Research

It is unrealistic today for any one effort to build a complete online education environment. Rather one must integrate a system from a variety of different sources. These could include commercial education software providers like Blackboard [5] and WebCT [53] but even more important will be systems and technologies designed for the much larger Web browsing and e-commerce arenas. Several powerful technologies (such as CORBA and Jini) and systems (such as E-Speak and iPlanet [14,27]) are emerging as candidate frameworks to integrate distributed information systems. We intend to make use of these powerful frameworks to form the base of our virtual university. Currently we expect to use the Ninja system from UCB [36] but we have only just started detailed evaluation and expect the number of possible choices to grow.

We will build education-specific portals as a set of special services on top of this framework. These must support the special collaborative needs of education and special services such as assessment, performance (grading) support, annotation. There are also distinctive "educational objects" – quizzes, homework, glossaries as well as the curriculum pages with appropriate hierarchical structure [18]. These will need special XML support and here we will adopt local standards as necessary and evolve these as international community efforts (such as IMS [26] and the IEEE Learning Technology Standards Committee [25]) mature. We will of course pay attention to support for key capabilities such as displaying mathematics on the Web [21] and standards for graphics (Java3D, VML, X3D etc.). This distributed object based distributed system will be designed to support curriculum material built in any web authoring system and specified either statically or dynamically (from a database). This simple statement is not easy to satisfy, as it requires unification of services such as those for customization, collaboration and events. This is a key research area as such unified services are essential for the basic strategy of allowing components from multiple academic and commercial sources. A simpler version of this challenge is well-defined XML interfaces to allow interoperability of data streams.

We expect commercial portal technology to support user customization of the environment, and we have already indicated that the base service (event logging) is expected to be useful both in assessment and individualization of the learning environment. This includes two types of capabilities. Firstly the capability, probably XML based, to pick and use the components shown on a particular web-page (portal). We have designed a simple "portalML" to describe layout and source of page components and further their collaborative structure [20]. We expect this XML syntax to be a reasonable start but that we will switch to community standards as they become accepted. More interesting than this powerful but straightforward XML specification of dynamic pages, is the methodology for tracking user interactions with the user environment. As discussed in the Syracuse theses of Lee and Sen [30,43], this can be done server side when it reduces to the classic analysis of Web Server accesses logs. More interesting is the tracking of client side events where the challenge is basically datamining user relevant information. We will on one hand build in support for this as part of our event service and research extensions of the simple analyses in the two theses to automatically derive user profile and learning assessment information. This client side event information can be used to support universal access as described by Fox and Gilman from the Wisconsin Trace center [19].

Our web-based virtual university approach implies that collaboration is a service that shares web-based distributed objects [41]. Previous systems have tended to support either synchronous or asynchronous collaboration modes, but based on our current experience we will unify them for this proposal. Initial synchronous deliveries have has some success using systems like Microsoft NetMeeting, NCSA's Habanero [23] and Syracuse's TangoInteractive [47]. However the new requirements imply we will not use these, but rather build collaboration on the event service of our base (Ninja or equivalent) framework. We will allow this to support either synchronous delivery or event archiving and later delivery of a session. Session control will be implemented in XML using the generalized portalML described above [20]. We have found that developing

shared animations (for education) is too difficult in current systems like TangoInteractive, which only easily support complex collaboration-aware applications. We will use VNC [51] or equivalent technology to allow both shared display and collaboration-unaware applications, which are less flexible but much easier to author. One important research issue will be the techniques needed to provide this unified approach to collaboration.

One continual area of difficulty is the variable quality in digital audio video conferencing, and here higher speed networking and quality of service will address some of the difficulties. We will track the ANL/NCSA Access Grid project [1] at the high end, but for many educational uses commercial systems like RealAudio/Video can be used. In our multi-paradigm framework, we will allow use of the more reliable (as larger buffers) technologies when interactive audio-video interactions are not essential.

5: Management Plan and Budget

The principal investigator has substantial experience with running large multi-institutional projects funded by NSF and DARPA as both project PI and co-PI. For a project of this size, we intend a steering committee containing leaders of technical activities and site representatives. This will discuss and approve major decisions. There will be an established oversight group, which will review general approach and supply vision and connectivity to national scene. This will help in the qualitative assessment plan of Sec. 3. The proposed budget is approximately $700K per year for five years. We see that the need to iteratively develop and assess new curriculum requires the relatively long five-year duration. The budget is split into activities as follows: Technology $175K, Assessment $125K, and the remainder apart from management and meeting costs to courseware development and network building.

6: Participating Institutions

The principal investigator Geoffrey Fox has moved from Syracuse University (CSIT) to the Department of Computer Science and new School of Computational Science and Information Technology at Florida State and brings substantial experience in both collaboration technology and novel computer science (Internetics) curriculum [16,17]. This was developed and delivered with Nancy McCracken at Syracuse, Jackson State and other participants. This work was sponsored by the Programming Environment & Training (PET) effort of the DoD Major Shared Resource Centers program - led by the NSF ERC at Mississippi State. It involved regular semester undergraduate and graduate CS courses, which were later, delivered by JSU to other HBCU's – the prototype of our proposed HBCU college network. Initially funded by NSF in 1990 as an NSF Engineering Research Center (ERC), the Computational Field Simulation activity at Mississippi State is a multi-disciplinary academic research center - now funded at approximately $15M annually by NSF, DoD, NASA,

Jackson State University (JSU), is the urban university of Mississippi and enrolls approximately 6,500 students. The primary goal of the School of Science and Technology, and the new School of Engineering, is to develop top quality scientists and engineers who can advance knowledge and address the technical problems facing the nation and the world. Particularly relevant to this proposal, JSU has graduated more African Americans in Computer Science than any other university in the United States. Among African Americans in Mississippi Institutions of Higher Learning, JSU has enrolled 53% of all Chemistry majors, 54% of all Biology majors, 66% of all Computer Science majors, 69% of all Mathematics majors, and 80% of all Physics and Atmospheric Sciences majors. Thus, JSU will continue to provide significant numbers of technical graduates for the current and future workforce.

Florida Agricultural & Mechanical University, founded in 1887, is an HBCU land-grant institution, which educates approximately 12,000 minority students each year. The Computer and Information Science department has a 94% minority population of approximately 600 undergraduates and 25 graduate students. It brings expertise in assessment and the use and evaluation of Internet courses.

FSU is also represented by the ODDL, which supports distance learning with the principle that the same education should be available to all FSU students, whether residential or distance. Their current model includes strong materials-based support for teacher and learner; optimal use of Internet bandwidth for communication, interactivity, and delivery; and a mentor system that provides low-ratio student support and scalability at the faculty level. This project will leverage ODDL's existing assessment unit. ODDL and CSIT combined with a rapid expansion of the FSU computer science department reflect the commitment of FSU to the teaching of Information Technology and its use in all aspects of research and education. Note that in 1999, there were 55 courses offered on-line at FSU to a total of 1800 students; this statistic is increasing rapidly and excludes "web-enhanced" courses.