

**INFORMATION ABOUT PRINCIPAL INVESTIGATORS/PROJECT DIRECTORS(PI/PD) and
co-PRINCIPAL INVESTIGATORS/co-PROJECT DIRECTORS**

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PI/PD Name: Brad A Myers

Gender: Male Female

Ethnicity: (Choose one response) Hispanic or Latino Not Hispanic or Latino

Race:
(Select one or more)

American Indian or Alaska Native
 Asian
 Black or African American
 Native Hawaiian or Other Pacific Islander
 White

Disability Status:
(Select one or more)

Hearing Impairment
 Visual Impairment
 Mobility/Orthopedic Impairment
 Other _____
 None

Citizenship: (Choose one) U.S. Citizen Permanent Resident Other non-U.S. Citizen

Check here if you do not wish to provide any or all of the above information (excluding PI/PD name):

REQUIRED: Check here if you are currently serving (or have previously served) as a PI, co-PI or PD on any federally funded project

Ethnicity Definition:

Hispanic or Latino. A person of Mexican, Puerto Rican, Cuban, South or Central American, or other Spanish culture or origin, regardless of race.

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PI/PD Name: Ruth W Chabay

Gender: Male Female
Ethnicity: (Choose one response) Hispanic or Latino Not Hispanic or Latino

Race:
(Select one or more)
 American Indian or Alaska Native
 Asian
 Black or African American
 Native Hawaiian or Other Pacific Islander
 White

Disability Status:
(Select one or more)
 Hearing Impairment
 Visual Impairment
 Mobility/Orthopedic Impairment
 Other _____
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PI/PD Name: Sara B Kiesler

Gender: Male Female
Ethnicity: (Choose one response) Hispanic or Latino Not Hispanic or Latino

Race:
(Select one or more)
 American Indian or Alaska Native
 Asian
 Black or African American
 Native Hawaiian or Other Pacific Islander
 White

Disability Status:
(Select one or more)
 Hearing Impairment
 Visual Impairment
 Mobility/Orthopedic Impairment
 Other _____
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PI/PD Name: Joel M Smith

Gender: Male Female
Ethnicity: (Choose one response) Hispanic or Latino Not Hispanic or Latino

Race:
(Select one or more)
 American Indian or Alaska Native
 Asian
 Black or African American
 Native Hawaiian or Other Pacific Islander
 White

Disability Status:
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PI/PD Name: Peter A Steenkiste

Gender: Male Female
Ethnicity: (Choose one response) Hispanic or Latino Not Hispanic or Latino

Race:
(Select one or more)
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 Asian
 Black or African American
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COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

| | | | | | | |
|--|-------------------------|--|---|--|--------------------------------|--|
| PROGRAM ANNOUNCEMENT/SOLICITATION NO./CLOSING DATE/if not in response to a program announcement/solicitation enter NSF 00-2 | | | | | FOR NSF USE ONLY | |
| NSF 99-167 | | | 01/05/00 | | NSF PROPOSAL NUMBER | |
| FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S) (Indicate the most specific unit known, i.e. program, division, etc.) | | | | | | |
| INFORMATION TECHNOLOGY RESEARC | | | | | | |
| DATE RECEIVED | NUMBER OF COPIES | DIVISION ASSIGNED | FUND CODE | DUNS# (Data Universal Numbering System) | FILE LOCATION | |
| | | | | | | |
| EMPLOYER IDENTIFICATION NUMBER (EIN) OR TAXPAYER IDENTIFICATION NUMBER (TIN) | | SHOW PREVIOUS AWARD NO. IF THIS IS <input type="checkbox"/> A RENEWAL <input type="checkbox"/> AN ACCOMPLISHMENT-BASED RENEWAL | | IS THIS PROPOSAL BEING SUBMITTED TO ANOTHER FEDERAL AGENCY? YES <input type="checkbox"/> NO <input checked="" type="checkbox"/> IF YES, LIST ACRONYMS(S) | | |
| 250969449 | | | | | | |
| NAME OF ORGANIZATION TO WHICH AWARD SHOULD BE MADE | | | ADDRESS OF AWARDEE ORGANIZATION, INCLUDING 9 DIGIT ZIP CODE | | | |
| Carnegie-Mellon University | | | H.B.H. 3000 | | | |
| AWARDEE ORGANIZATION CODE (IF KNOWN) | | | 5000 Forbes Avenue | | | |
| 0001057000 | | | Pittsburgh, PA. 152133815 | | | |
| NAME OF PERFORMING ORGANIZATION, IF DIFFERENT FROM ABOVE | | | ADDRESS OF PERFORMING ORGANIZATION, IF DIFFERENT, INCLUDING 9 DIGIT ZIP CODE | | | |
| PERFORMING ORGANIZATION CODE (IF KNOWN) | | | | | | |
| IS AWARDEE ORGANIZATION (Check All That Apply) (See GPG II.D.1 For Definitions) <input type="checkbox"/> FOR-PROFIT ORGANIZATION <input type="checkbox"/> SMALL BUSINESS <input type="checkbox"/> MINORITY BUSINESS <input type="checkbox"/> WOMAN-OWNED BUSINESS | | | | | | |
| TITLE OF PROPOSED PROJECT ITR/HCI:Using Networked Hand-Held Computers to Enhance Learning | | | | | | |
| REQUESTED AMOUNT \$ 4,110,515 | | PROPOSED DURATION (1-60 MONTHS) 60 months | | REQUESTED STARTING DATE 09/01/00 | | SHOW RELATED PREPROPOSAL NO., IF APPLICABLE |
| CHECK APPROPRIATE BOX(ES) IF THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW | | | | | | |
| <input type="checkbox"/> BEGINNING INVESTIGATOR (GPG 1.A.3) | | | <input type="checkbox"/> VERTEBRATE ANIMALS (GPG II.D.12) IACUC App. Date _____ | | | |
| <input type="checkbox"/> DISCLOSURE OF LOBBYING ACTIVITIES (GPG II.D.1) | | | <input type="checkbox"/> HUMAN SUBJECTS (GPG II.D.12) | | | |
| <input type="checkbox"/> PROPRIETARY & PRIVILEGED INFORMATION (GPG II.D.10) | | | Exemption Subsection _____ or IRB App. Date _____ | | | |
| <input type="checkbox"/> NATIONAL ENVIRONMENTAL POLICY ACT (GPG II.D.10) | | | <input type="checkbox"/> INTERNATIONAL COOPERATIVE ACTIVITIES: COUNTRY/COUNTRIES _____ | | | |
| <input type="checkbox"/> HISTORIC PLACES (GPG II.D.10) | | | <input type="checkbox"/> FACILITATION FOR SCIENTISTS/ENGINEERS WITH DISABILITIES (GPG V.G.) | | | |
| <input type="checkbox"/> SMALL GRANT FOR EXPLOR. RESEARCH (SGER) (GPG II.D.12) | | | <input type="checkbox"/> RESEARCH OPPORTUNITY AWARD (GPG V.H) | | | |
| <input type="checkbox"/> GROUP PROPOSAL (GPG II.D.12) | | | | | | |
| PI/PD DEPARTMENT Human Computer Interaction Institute | | | PI/PD POSTAL ADDRESS 5000 Forbes Ave. | | | |
| PI/PD FAX NUMBER 412-268-1266 | | | HCI, CMU | | | |
| | | | Pittsburgh, PA 152133891 | | | |
| | | | United States | | | |
| NAMES (TYPED) | | High Degree | Yr of Degree | Telephone Number | Electronic Mail Address | |
| Brad A Myers | | Ph.D. | 1987 | 412-268-5150 | bam@cs.cmu.edu | |
| Ruth W Chabay | | Ph.D. | 1975 | 412-268-5714 | rchabay@andrew.cmu.edu | |
| Sara B Kiesler | | Ph.D. | 1965 | 412-268-2848 | kiesler+@andrew.cmu.edu | |
| Joel M Smith | | PhD | 1987 | 909-621-8174 | smithjo@cgs.edu | |
| Peter A Steenkiste | | Ph.D | 1987 | 412-268-3261 | prs@cs.cmu.edu | |

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 application.

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 |
|---------------------------------------|-----------|---|------|
| PI/PD Brad A Myers | | *ON FASTLANE SUBMISSIONS* SSNs are confidential and are not displayed | |
| Co-PI/PD Ruth W Chabay | | | |
| Co-PI/PD Sara B Kiesler | | | |
| Co-PI/PD Joel M Smith | | | |
| Co-PI/PD Peter A Steenkiste | | | |

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 Federal debt status, debarment and suspension, drug-free workplace, and lobbying activities (see below), as set forth in Grant Proposal Guide (GPG), NSF 00-2. 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).

In addition, if the applicant institution employs more than fifty persons, the authorized official of the applicant institution is certifying that the institution has implemented a written and enforced conflict of interest policy that is consistent with the provisions of Grant Policy Manual Section 510; that to the best of his/her knowledge, all financial disclosures required by that conflict of interest policy have been made; and that all identified conflicts of interest will have been satisfactorily managed, reduced or eliminated prior to the institution's expenditure of any funds under the award, in accordance with the institution's conflict of interest policy. Conflict which cannot be satisfactorily managed, reduced or eliminated must be disclosed to NSF.

Debt and Debarment Certifications

(If answer "yes" to either, please provide explanation.)

Is the organization delinquent on any Federal debt?

Yes

No

Is the organization or its principals presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from covered transactions by any Federal department or agency?

Yes

No

Certification Regarding Lobbying

This certification is required for an award of a Federal contract, grant, or cooperative agreement exceeding \$100,000 and for an award of a Federal loan or a commitment providing for the United States to insure or guarantee a loan exceeding \$150,000.

Certification for Contracts, Grants, Loans and Cooperative Agreements

The undersigned certifies, to the best of his or her knowledge and belief, that:

(1) No federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.

(2) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with this Federal contract, grant, loan, or cooperative agreement, the undersigned shall complete and submit Standard Form-LLL, "Disclosure Form to Report Lobbying," in accordance with its instructions.

(3) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers including subcontracts, subgrants, and contracts under grants, loans, and cooperative agreements and that all subrecipients shall certify and disclose accordingly.

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by section 1352, title 31, U.S. Code. Any person who fails to file the required certification shall be subject to a civil penalty of not less than \$10,000 and not more than \$100,000 for each such failure.

| AUTHORIZED ORGANIZATIONAL REPRESENTATIVE | SIGNATURE | DATE |
|---|---|-----------------------------------|
| NAME/TITLE (TYPED) Susan Burkett, Associate Provost | | |
| TELEPHONE NUMBER 412-268-8746 | ELECTRONIC MAIL ADDRESS sd0c@andrew.cmu.edu | FAX NUMBER 412-268-6279 |

*SUBMISSION OF SOCIAL SECURITY NUMBERS IS VOLUNTARY AND WILL NOT AFFECT THE ORGANIZATION'S ELIGIBILITY FOR AN AWARD. HOWEVER, THEY ARE AN INTEGRAL PART OF THE INFORMATION SYSTEM AND ASSIST IN PROCESSING THE PROPOSAL. SSN SOLICITED UNDER NSF ACT OF 1950, AS AMENDED.

PROJECT SUMMARY

Using Networked Hand-Held Computers to Enhance Learning (Pre-Proposal)

Increasingly, students and instructors have hand-held computers, such as Palm Pilots and Windows CE devices. This trend can only accelerate as the devices get more affordable and more functional, and as new sizes are developed, such as inexpensive tablet computers. We propose a broad multi-disciplinary research project to study many ways for using hand-held computers connected to a wireless network in educational settings. For example, the instructor's hand-held can be used to make the presentation of lectures and labs go more smoothly. The student's hand-helds can be used to make note-taking more effective, to support testing and voting, to encourage full-class participation in discussions, and to facilitate group interactions. We will leverage off of a number of existing efforts to make this research possible, including: the ubiquitous "Wireless Andrew" network at Carnegie Mellon University which allows hand-helds to communicate with each other and with the instructor's computer; a grant from Hewlett-Packard of \$304,000 in equipment which will include 330 hand-held computers; and on-going collaborations with a number of professors who are committed to using the proposed technology in their classrooms. The proposed grant is necessary to explore the educational applications of these technologies.

This research will involve developing, deploying and evaluating many technologies, including the following:

- Software to support note-taking. Research has shown that the most effective note-taking style is the "skeleton-notes" approach, where students are given part of the lecture material. Distributing this material, along with the professor's materials, electronically to the students' hand-helds rather than on paper will have a number of advantages to the instructor and the student. The research will include studying the appropriate techniques for note-taking on devices with various sizes and input/output methods.
- Software to support in-class quizzes, grading homeworks, and voting. Questions will be distributed in real-time to the student's hand-helds in class, and students will answer using the hand-held. This will allow instructors to immediately gauge student knowledge. This can also be used to encourage full-class participation, since the instructor can easily monitor who has answered questions. These techniques have been conclusively demonstrated to increase learning.
- Networking software to support secure and flexible protocols for use over a wireless network. In particular, we need reliable multicast so the professor can efficiently send images to all hand-helds in the class, and security so that cheating during tests given on the hand-helds can be detected and prevented. We will extend our existing work on active networks and intelligent proxies to meet these new requirements.
- Software to support collaboration, communication and management of group work products. Effective teamwork is increasingly important in today's workplace and in the workplace of tomorrow. To prepare students for the realities of the workplace, their academic experience now often includes substantial team-based projects. Having software on hand-helds to help with group activities will enable students to use team-support tools wherever they work and meet.

An important component of our proposal is the significant multi-disciplinary participation across the campus. To achieve the proposed objectives, we will need to perform basic research in the areas of Computer Science and Networking, Human-Computer Interaction, Computer-Supported Cooperative Work, and Educational Technology. Members of our team specialize in each of these areas. We also have faculty who are enthusiastic about using these technologies in various large courses in Chemistry, Statistics, Social and Decision Sciences, and Computer Science. Furthermore, Carnegie Mellon's Center for Innovation in Learning and the new Office of Technology in Education will be actively involved to help insure that the technology does enhance learning.

Many of the areas of the ITR solicitation are addressed in our proposal, including Information Technology Education and Workforce (for education), Human-Computer Interaction (for ubiquitous computing, interfaces for school children, and collaborative use of computer systems and networks), and Scalable Information Infrastructure (for scalable mobile wireless access).

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PROJECT DESCRIPTION, GOALS AND OBJECTIVES

1. Introduction

There are many signs of the approach of the “ubiquitous computing” [20] era. People are carrying Personal Digital Assistants (PDAs), such as Palm Pilots or Windows CE devices, and therefore have computing with them everywhere. “Smart Environments,” where computing is embedded in offices and homes, are becoming a reality. Already, most conference rooms and classrooms at Carnegie Mellon University (CMU) have a built-in computer with a projector. And of course, every professor and most students have at least one computer on their desks in their offices. Most companies are similar, since virtually every white-collar worker today uses a computer. Homes are just starting to be set up with embedded computing [11].

One aspect of this technology that has not been adequately studied is how a user will use *multiple* devices at the same time, so the devices work seamlessly together. Most of the research and development about hand-held computers has focused on how they can be used to *replace* conventional computers for when a regular computer is not around. The conventional model for PDAs is that the data is “synchronized” with a regular computer once a day using the supplied cradle, and otherwise the PDA works independently. This will soon change. CMU has installed a Wavelan wireless network throughout the campus, in a project called “Wireless Andrew” [8]. Many Windows CE hand-held computers can be connected to this wireless network using a Wavelan PCMCIA card. Next year, the Bluetooth standard for small device wireless radio communication [5] will finally be available, and most PDAs, cell-phones, and other computerized small devices are expected to support it. Therefore, we expect that connecting the PCs and hand-helds together will no longer be an occasional event for synchronization.

Instead, the devices will frequently be in close, interactive communication.

The proposed research studies how such communicating hand-held computers can enhance the learning experience for students, and the teaching experience for instructors. We are primarily aiming at university education as our application area. This is appropriate since introductory classes tend to include large lectures, which are well known to be a less effective way to learn material. Techniques like those that we will use on hand-helds have been demonstrated to improve learning in large classes. Also, many classes include collaborative group projects that are currently not being supported by technology. These group projects form an excellent test-bed for our collaborative technologies. We expect that much of the proposed research will also apply to K-12 education, especially the results on testing and encouraging full-class participation. Much of the research will also be relevant to work situations, especially presentations and meetings, since these have many aspects in common with educational activities.

2. Research Overview

There are many important issues that must be investigated before hand-helds can be effectively integrated into a seamless academic information environment. We propose research in many areas in order to make these technologies truly useful:

Research in Human-Computer Interaction (HCI) and Computer-Supported Cooperative Work (CSCW):

- **Multi-Device User Interfaces:** We will investigate the most effective ways to have a user interface across the multiple devices that a person has available at the same time. For example, when an instructor is using a hand-held computer to control a presentation running on a laptop, part of the user interface will be on the laptop and part will be on the hand-held. Although there is much research on multi-modal user interfaces (e.g., using speech and gestures at the same time), there has been little prior work on using multiple computing *devices* at the same time.
- **Fluid Information Exchange:** New research is needed on user interface techniques for fluid information exchange and sharing among the hand-helds and regular computers. The “hot-sync” model of today’s PDAs, and the conventional mechanisms for regular computers, are extremely awkward for group sharing of information across different devices. Our prior work on “clipboard sharing” [13] where you can move information using a Copy operation on one device and a Paste operation on another, as well as work by others on “Pick-and-Drop” [17] and other techniques, will be useful starting points, but more work is needed.

- **UIs for Different Devices:** Most of today's HCI research focuses on screens of approximately the same size with approximately the same input devices. However, hand-held computers have significantly different size screens with very different input technologies. For example, the Palm Pilot screen is 140 by 140 pixels and grayscale, the Cassiopeia E-10's screen is 240 by 320 grayscale, the NEC MobilePro 750C PDA is 640 by 240 in color, and future versions may be even more diverse. For input, the palm-size PDAs use a gestural alphabet on a touch screen with a few hardware buttons, whereas other PDAs have tiny keyboards. In a university environment, students and faculty use a variety of devices. Therefore, we will study user interface techniques that can span all these devices, as well as architectures that allow the software designer to specify the user interface once and have it automatically be adapted to the characteristics of each device.
- **Group Configuration Control:** One important, but little explored, area is configuration set-up and control. When 200 students walk into a classroom, they will need to be quickly logged in to the class group so they can get the material specifically for the current class. When three people meet in a room, they should be able to quickly form a sub-group. The Wavelan wireless technology by design does not identify where people are physically, so a different mechanism is required. We might use the Infrared communication built into most hand-held devices as a short-range set-up mechanism. Another approach might be to use a server machine on the network to help with group formation. Both systems and user interface issues are important because if it is awkward for users to identify themselves (log in) and connect to the appropriate groups, the technologies will unduly delay classes and meetings, or will simply not be used.
- **Transparent Group Support:** We want to provide technological support for group work with as little overhead as possible, so the technology is "transparent" to users. There have been many technologies created to support group work. Some have shown promise, and a few have been demonstrated to significantly improve group performance on specific tasks, such as brainstorming and organizing [9, 16]. Currently, most of these (such as Group Decision Support Systems – GDSSs) are physically bound to rooms with built-in computers, significantly decreasing their usefulness and making impromptu meetings virtually impossible. With hand-held computers, these techniques can be used whenever and wherever they are needed. We will investigate which of the established group support techniques can be effectively used by small and large groups of students for group projects and group meetings. We will also develop new techniques specifically targeted at students' needs.

Research in Computer Science and Systems:

- **Efficient Reliable Multicast:** When the instructor displays a new view or slide on the main screen in a classroom, all of the students' hand-helds should be sent the image so students can immediately begin taking notes on it. Since each image may be half a megabyte, we don't want to send it individually to 200 hand-helds. Therefore, a technique is needed to reliably send ("multicast") the picture to all the students at the same time.
- **Security for Wireless Communication:** When the instructor is using the hand-helds to administer a test, we must insure that one student does not send back answers claiming that they came from a different student. Furthermore, we want to prevent students from conferring with each other by sending messages using their hand-helds. The instructor may also want to prevent students from accessing the Internet while taking a test. We will investigate mechanisms to reliably monitor and control the network communication to solve these issues.
- **Supporting Multi-Device Interfaces:** We will create libraries that support architectures and protocols for having applications that span multiple computing devices at the same time. Today, developing a multi-device application is more than twice as difficult as a conventional application, and we propose to provide tools to make this much easier.
- **Synchronizing Notes to Simulations:** We (and others) already have techniques so that the notes that a student takes on their hand-held can be synchronized with a PowerPoint or web-based presentation. We propose to extend this to provide an architecture where the notes can be connected to specific points in many other kinds of presentations, including live simulations. Then, it will be much easier later for students to re-create the simulations, and see their notes in context. The challenge is to provide tools that will make implementing these connections easier.

Research in Educational Technology:

- **“Concept Tests” and other “Active Learning” Techniques on Hand-Helds:** It is an unfortunate reality that much of a student’s time is spent in traditional lecture courses where one-way communication encourages them to become passive recipients of information rather than active learners. Discussion and project courses help remedy this, but lecture courses will remain a predominant component of education and so it is well worth exploring ways to improve the standard lecture format. A particularly successful intervention has been the use of “concept tests” [12], in which the instructor poses a conceptual multiple-choice question at several points in a lecture. Students both discuss the question with their neighbors and then indicate their answer. The success of this simple intervention clearly indicates the benefits to be gained by bringing routine and inclusive two-way communication into lecture courses. We propose a qualitative improvement in the flexibility of this two-way communication, by providing every student in a course with a hand-held computer that communicates with the instructor’s computer via Wireless Andrew. The research involves evaluating and refining this and other “active learning” techniques for use with hand-helds.
- **Students’ Note-Taking:** The “skeleton-notes” approach to note taking, whereby students are given handouts that contain part of the lecture material (such as figures, problem statements etc.) with large spaces for students to take notes, has been demonstrated to be one of the most effective for learning. We propose to implement this and other note-taking strategies on hand-helds. The advantages of electronic notes are that they would be searchable, and the teacher could be sure everyone has an up-to-date copy of the material without the trouble of printing a lot of papers before hand. These notes will be linked to the current slide, so that later the student will be able to review their notes in context. There is evidence of increased learning when one can recall both the material and the context in which it was learned [19]. Taking advantage of the wireless network, we will not need to download the entire presentation to the hand-held (since it may not fit in many cases), and instead we will only keep track of the notes and the links to the presentation. After the lecture, the links will retrieve the presentation off of the Internet, and synchronize the notes appropriately.
- **Supporting Student Groups:** Today’s workplace increasingly emphasizes teamwork. At CMU, students complete substantial-sized team projects as part of their courses, often for real clients. Students in these project courses deal with all of the challenges common to industry project teams – difficulty in coordinating schedules, synchronizing and stabilizing their work products, and communicating effectively with each other. Effective coordination, communication, and use of shared resources are crucial skills for team members to master. The use of high quality electronic tools to support development team efforts can play an important and useful role in facilitating successful team collaboration and project development. We propose to investigate how the existing techniques for group support can be adapted for hand-held computers, and what new techniques arise from the ability to carry these devices around while students are still communicating. We expect this to enable a whole new class of group support tools.

3. Why at CMU?

Our group at CMU is uniquely qualified to investigate these issues. This stems from a number of scientific and organizational features of our team and the university. First, CMU provides significant encouragement to interdisciplinary research, which is clearly required to study the issues around networked use of hand-helds in education. Many of us belong to units that are inherently interdisciplinary – the Human-Computer Interaction Institute is comprised of faculty from Computer Science, Psychology, Design and others, and the Center for Innovation in Learning (CIL) has faculty from Physics, Psychology and others. We have experience working together and supporting and managing large projects that span many areas.

Another advantage we have is the significant existing research here on hand-helds, networks, educational technology and other areas. As discussed below, we have significant on-going research projects that can supply some of the needed expertise and technology. This will also allow our proposed project to get off the ground quickly. Furthermore, CMU, and the principals on this proposal in particular, have a long tradition of developing systems that are robust enough to be deployed and widely used.

CMU has a long-term commitment to using and studying effective ways to use technology in education, as demonstrated by the Center of Innovation in Learning (CIL), the Technology Enhanced Learning Lab, and the new Office

of Technology in Education. CMU provides funding and support for faculty who want to use technology in classes, and a number of faculty in Chemistry, Statistics, Decision Sciences, Computer Science and others, have committed to using the software proposed here when it is ready. Furthermore, we are one of the few sites that have demonstrated through formal evaluation significantly improved learning using educational technology. CIL, which will act as consultants for this work, carries out serious research and development in the area of undergraduate education, including studies of student learning, development of novel curricula, and assessment of courses (e.g., [1, 18]). CIL faculty members have extensive experience with the use of technology in undergraduate education. CIL will consult on assessment and on setting priorities for which technological capabilities are more likely or less likely to be productive educationally. CIL will also provide valuable advice on how best to try out innovations in ongoing classes.

Finally, with the Wireless Andrew project [8], Carnegie Mellon University has created a test bed for seamless access to wireless data services that uses high-speed wireless local area network (Lucent's *Wavelan*) technology. Our infrastructure is the largest wireless LAN anywhere. With Wireless Andrew, users can roam about the campus and access the Internet and other networks from laptop and hand-held computers while wireless connections are maintained automatically. This makes the mobile computer as effective for most purposes as a wired desktop machine – but far more convenient. Furthermore, since the devices can be carried into environments where there are existing computers, many multi-device issues arise. The Wireless Andrew infrastructure now has more than 100 base stations and provides data services at speed of two megabits per second to about half the campus area. During academic year 1999-2000 we are extending the high-speed wireless service to the entire campus, installing about 400 base stations. This expansion has major support from Lucent Technologies and additional support from Cisco Systems. Hewlett Packard has agreed to donate 330 hand-held computers of various kinds, valued at \$304,000, to support research into educational uses of wirelessly-connected hand-helds. The research proposed here will enable us to fully investigate some of the exciting educational applications of this technology, and the HCI and CS research issues that arise.

4. Research on Using Hand-helds and PCs Together

One foundation for the proposed research is the substantial progress already made in the Pebbles project on using multiple hand-held computers at the same time as a desktop or laptop PC [13-15]. We are studying group use of hand-helds in meetings, so that each person can use their hand-held to control the PC's cursor and keyboard. Another application allows a presenter to use PowerPoint on a PC in the regular way, but to use a hand-held to change slides, to view a thumbnail of the slide, to hand-write notes and scribbles, to see the notes attached to the slide, and to see the list of titles of all slides. We propose to extend this application to handle the student's note-taking. The Pebbles project has developed a preliminary architecture that will be expanded to support the multi-device applications proposed here.

5. Intelligent Networking Support

Having groups of students use a variety of hand-held devices for tasks such as group projects, informal collaboration and exams raises significant new challenges for the network. We focus on two areas of research: traffic control and the use of intelligent "proxies" (a server that supports mobile devices is sometimes called a "proxy" because it connects the mobile host to the wired network). Hand-held devices hold the promise of ubiquitous connectivity, but in some environments, it may be important to *restrict* connectivity. For example, in an exam, the students may be allowed to access certain resources over the network (e.g. a compute server that runs simulation tools that are needed for some of the problems, or a specific web server with data sets), but other types of communication are prohibited (e.g. searching the course web site or chatting with fellow students). Meeting these constraints requires traffic policing at a much finer granularity than is done today. We propose a network monitor for all of the wireless traffic in the classroom that will check for violations. This is non-trivial task for a variety of reasons. First, the hand-held devices are owned by students and are thus not "trusted," i.e., we can make only minimal assumptions about the software on the hand-held devices. Second, whether traffic is acceptable depends in part on the applications that send and receive the traffic, so the monitor will have to consider application headers in the packet, not only the traditional network headers. Finally, what traffic is allowed depends heavily on the context, i.e. the specific exam, the policy on what collaboration is allowed, etc., so the system must be very flexible. To achieve these goals, we will use "active networking" techniques, where application- or user-specific functionality can be introduced in the network. This will be an extension of our on-going Darwin research project [2].

A second problem is that hand-held devices have relatively limited resources (CPU cycles, memory, network bandwidth, etc.). Given that hand-held devices (or more generally, portable computers) can have very different capabilities, a server that performs computation on behalf of such a device will often have to customize the task to the capabilities of the device. There has been much research in the area of proxies for mobile devices (e.g. [4, 10]). However, most of this work has focused on supporting fairly generic services, such as distilling web pages [3]. In contrast, our educational environment will need more specialized services. Different courses will need types of services that are specialized for the educational environment. We propose to perform research on supporting such specialized proxies, using application-specific “multicast” as our focus since it plays a central role in this environment. Multicast is a way of transmitting the same information to a large number of destinations. With the right support in the network, multicast can use the network much more efficiently since it only requires the source to send the message once instead of sending one copy of the message for every receiver. Multicast is especially important in wireless environments where bandwidth is a limited resource. In our context, we need application-specific multicast in the sense that different groups of receivers may need slightly different versions of the data because of the diversity of the hand-held devices or differences in the requirements of some of the receivers. We plan to use proxies to perform the necessary translation of the information for groups of receivers.

6. Educational Applications

A clear signal from education research is the value of active learning in college classes in contrast to passive listening [6]. Such activities in large lectures include “concept tests” [12], group problem-solving [7], and desktop experiments [1]. It has already been shown that hand-held devices can play a useful role in providing real-time feedback on multiple-choice concept tests from individual students to instructors. We are interested in exploring the educational value of more sophisticated modes of use in the service of active learning, including student collaboration.

Some examples of modes that we believe could be valuable but which cannot be tried out without significant investment in software and hardware infrastructure include: students could make measurements using an experiment kit and enter data into their hand-helds. The data would then be collected by the instructor’s computer, and compared and contrasted for the class. In some cases, sensors may be connected directly to the hand-held device, something that exists today but which should be networked. A group of students could draw pictures on their hand-held computers in the mode of a common blackboard that facilitates discussion. This is already being done with whiteboards, but can be awkward with most seating arrangements. Group problem solving can be displayed to the whole class and discussed. A related mode is discussion among students or with instructors. It is notoriously hard for students to communicate by email about science questions involving equations. A hand-held with stylus can offer a mechanism for drawing and displaying equations without the extreme awkwardness of using an equation editor. With appropriate networking this would be useful both in large lectures and in synchronous or asynchronous consultations and collaborations outside of class, sometimes in association with a desktop computer. Many other applications, including note-taking, coordination and testing will also be developed, deployed and evaluated.

7. Conclusions

Hand-held devices have the potential to extend the reach of computing beyond the desktop, creating the opportunity for a new level of access to information resources. When supported by wireless networks with on-line access to network resources (in contrast to the prevalent modes of disconnected, synchronized, or dial-up use), hand-held devices will be enabled as full peers within the campus computing environment with full-time access to all information resources.

The convergence of wireless technology and the explosion in low-cost, high-quality hand-held devices provides the emerging opportunity to address issues surrounding ubiquitous computing and continuous-access group oriented applications. Ubiquitous computing creates the potential to maximize information access and increase productivity of our community members. This generates opportunities to improve upon the success of individual campus units and the university as a whole, as more individuals have access to networked information that is unrestricted by location or physical connection. Further, by integrating hand-held devices as full peers, we are increasing the sheer percentage of the community who can participate in a computing environment (i.e. new users) while simultaneously increasing the amount of time all users can choose to access that environment. The proposed research will answer important research questions necessary for realizing this vision.

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E-mail: joelms+@andrew.cmu.edu

Education

Ph.D. History and Philosophy of Science, University of Pittsburgh, 1987. Dissertation: "The Status of Inconsistent Statements in Scientific Theory".

M.A. History and Philosophy of Science, University of Pittsburgh, 1984

M.S. Physics, Baylor University, 1982

B.S. Physics, Baylor University, 1979

B.A. Philosophy, Baylor University, 1976

Employment

Present Position: Director, Office of Technology in Education, Carnegie Mellon University.

1996-1999: Dean, Academic Information Services, MiraCosta College, Oceanside, California

1998-1999: Adjunct Associate Professor, Department of Philosophy, University of California, San Diego

1992-1996 Associate Provost for Information Technology and Associate Professor of Philosophy, Philosophy Department, The Claremont Graduate School, Claremont, California

1989-1992 Director of Educational Computing and Assistant Professor of Philosophy, Department of Philosophy and Religious Studies, Allegheny College, Meadville, Pennsylvania

1987-1989 Assistant Professor of History and Philosophy of Science, Department of History and Philosophy of Science, Indiana University, Bloomington, Indiana

Selected Publications

"Professors as Developers" in Les Lloyd (ed.), *Technology and Teaching : Case Studies on the Use of Computers, Networks, and Multimedia in the Classroom*. Information Today, Inc. 1997: pp: 275-286.

"What Steve Jobs Did Right, The Educational Potential of the Ideas Behind NeXTStep," *Educom Review*, (1994): 17-21.

"Scientific Reasoning or Damage Control: Alternative Proposals for Reasoning with Inconsistent Representations of the World." *Proceedings of the 1988 Biennial Meeting of the Philosophy of Science Association I* (1988): 241-248.

"Inconsistency and Scientific Reasoning." *Studies in History and Philosophy of Science* 19 (1988): 429-445.

"How Philosophy Misuses Its Past." In *Contemporary Essays on Greek Ideas*. Ed. Robert Baird, et al. Waco, Texas: Baylor University Press, 1987.

Peter A. Steenkiste

Address

Prof. Peter Steenkiste
School of Computer Science
Carnegie Mellon University
5000 Forbes Avenue
Pittsburgh PA, 15213

E-mail: prs@cs.cmu.edu

Education

Ph.D. in Electrical Engineering, Stanford University, 1987. Thesis: "LISP on a Reduced Instruction Set Processor: Characterization and Optimization", Advisor: Professor John Hennessy.

Master of Science in Electrical Engineering, Stanford University, 1983..

Electrical Engineer, University of Gent, Belgium, 1982. Thesis: "Digital Image Processing".

Employment

January 2000 – present: Associate Professor, Departments of Computer Science and of Electrical and Computer Engineering, Carnegie Mellon University.

July 1993 – December 1999: Senior Research Scientist in the School of Computer Science at Carnegie Mellon University. Courtesy appointment in the Department of Electrical and Computer Engineering (since Fall 1998).

July 1989 - June 1993: Research Scientist in the School of Computer Science at Carnegie Mellon University.

August 1987 - June 1989: Research Associate (postdoc) in the Department of Computer Science at Carnegie Mellon University.

Selected Publications

David Eckhardt and Peter Steenkiste, "Effort-Limited Fair (ELF) Scheduling for Wireless Networks", IEEE INFOCOM 2000, March 2000, Tel Aviv.

Prashant Chandra, Allan Fisher, Corey Kosak, T. S. Eugene Ng, Peter Steenkiste, Eduardo Takahashi, Hui Zhang, "Darwin: Customizable Resource Management for Value-Added Network Services", 6th International Conference on Network Protocols (ICNP'98), IEEE, Austin, October 1998, pages 177-188.

David Eckhardt and Peter Steenkiste, "Improving Wireless LAN Performance via Adaptive Local Error Control", 6th International Conference on Network Protocols (ICNP'98), IEEE, Austin, October 1998, pages 327-338.

David Eckhardt and Peter Steenkiste, "Measurement and Analysis of the Error Characteristics of an In Building Wireless Network", ACM SIGCOMM '96 Symposium, San Francisco, August 1996, pages 243-254.

Bruce Lowekamp, Nancy Miller, Dean Sutherland, Thomas Gross, Peter Steenkiste, and Jaspal Subhlok, "A Resource Query Interface for Network-Aware Applications", Cluster Computing, Baltzer Science Publishers, number 2, 1999, pages 139-151.

Diana Bajzek

Address

Diana Bajzek
Director of the Technology Enhanced Learning Lab
Carnegie Mellon University
5000 Forbes Avenue
Pittsburgh, PA 15213
E-mail: db33@andrew.cmu.edu

Education

B.S. Math, (primary electives in computer science) Carnegie Mellon University, 1970

Employment

1996-1999: Founder and Director, Technology Enhanced Learning Lab, Carnegie Mellon University.

1983-1999: Senior Consultant, Computing Services, Carnegie Mellon University.

1977-1983: Project programmer, Computer Science Dept., Carnegie Mellon University.

1970-1977: Systems programmer, Computer Science Dept., Carnegie Mellon University.

Selected Publications

M. Schmidt, W.H. Blackmon, D.R. Rehak, D. Bajzek (1998). "Online Art History: Design, Development and Review of an Interactive Course" in "WebNet 98", Proceedings of WebNet 98--World Conference on the WWW, Internet, & Intranet, Association for Advancement of Computing in Orlando, Florida.

SUMMARY PROPOSAL BUDGET YEAR 1

| ORGANIZATION Carnegie-Mellon University | | | | FOR NSF USE ONLY | | | |
|---|-------|------|------|---------------------------------|------------------------------|-----------------------------|-------------------------------------|
| | | | | PROPOSAL NO. | DURATION (months) | | |
| PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR Brad A Myers | | | | AWARD NO. | Proposed | Granted | |
| 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. | | Funds Requested By proposer | Funds granted by NSF (if different) |
| | CAL | ACAD | SUMR | | | | |
| 1. Brad A Myers - Sr. Research Scientist | 2.40 | 0.00 | 0.00 | \$ 122,474 | | | |
| 2. Diana M Bajzek - Sr. Multimedia Consultant | 2.40 | 0.00 | 0.00 | 75,932 | | | |
| 3. Ruth W Chabay - Sr. Research Scientist | 0.00 | 0.00 | 1.00 | 46,123 | | | |
| 4. Sara B Kiesler - Professor | 0.00 | 0.00 | 1.00 | 75,724 | | | |
| 5. Joel M Smith - Director Technology in Educati | 1.80 | 0.00 | 0.00 | 62,788 | | | |
| 6. (1) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE) | 1.00 | 0.00 | 0.00 | 47,918 | | | |
| 7. (6) TOTAL SENIOR PERSONNEL (1 - 6) | 7.60 | 0.00 | 2.00 | 430,959 | | | |
| B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS) | | | | | | | |
| 1. (0) POST DOCTORAL ASSOCIATES | 0.00 | 0.00 | 0.00 | 0 | | | |
| 2. (3) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.) | 12.00 | 0.00 | 0.00 | 467,156 | | | |
| 3. (6) GRADUATE STUDENTS | | | | 1,410,912 | | | |
| 4. (0) UNDERGRADUATE STUDENTS | | | | 0 | | | |
| 5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY) | | | | 0 | | | |
| 6. (0) OTHER | | | | 0 | | | |
| TOTAL SALARIES AND WAGES (A + B) | | | | 2,309,027 | | | |
| C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS) | | | | 219,688 | | | |
| TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C) | | | | 2,528,715 | | | |
| D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING \$5,000.) | | | | | | | |
| Computer Equipment | | | | \$ 100,440 | | | |
| TOTAL EQUIPMENT | | | | 100,440 | | | |
| E. TRAVEL | | | | 138,402 | | | |
| 1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS) | | | | | | | |
| 2. FOREIGN | | | | 0 | | | |
| F. PARTICIPANT SUPPORT COSTS | | | | | | | |
| 1. STIPENDS | \$ | 0 | | | | | |
| 2. TRAVEL | | 0 | | | | | |
| 3. SUBSISTENCE | | 0 | | | | | |
| 4. OTHER | | 0 | | | | | |
| (0) TOTAL PARTICIPANT COSTS | | | | 0 | | | |
| G. OTHER DIRECT COSTS | | | | | | | |
| 1. MATERIALS AND SUPPLIES | | | | 0 | | | |
| 2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION | | | | 13,227 | | | |
| 3. CONSULTANT SERVICES | | | | 0 | | | |
| 4. COMPUTER SERVICES | | | | 179,701 | | | |
| 5. SUBAWARDS | | | | 0 | | | |
| 6. OTHER | | | | 34,117 | | | |
| TOTAL OTHER DIRECT COSTS | | | | 227,045 | | | |
| H. TOTAL DIRECT COSTS (A THROUGH G) | | | | 2,994,602 | | | |
| I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) | | | | | | | |
| % of MTDC (Rate: 50.6000, Base: 2205362) | | | | | | | |
| TOTAL INDIRECT COSTS (F&A) | | | | 1,115,913 | | | |
| J. TOTAL DIRECT AND INDIRECT COSTS (H + I) | | | | 4,110,515 | | | |
| 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) | | | | \$ 4,110,515 | | | |
| M. COST SHARING PROPOSED LEVEL \$ | | | | 0 | AGREED LEVEL IF DIFFERENT \$ | | |
| PI / PD TYPED NAME & SIGNATURE* | | | DATE | FOR NSF USE ONLY | | | |
| Brad A Myers | | | | INDIRECT COST RATE VERIFICATION | | | |
| ORG. REP. TYPED NAME & SIGNATURE* | | | DATE | Date Checked | Date Of Rate Sheet | Initials - ORG | |

SUMMARY PROPOSAL BUDGET COMMENTS - Year 1

Other Senior Personnel

| Name - Title ----- | Cal --- | Acad ----- | Sumr ----- | Funds Requested ----- | | |
|--|------------|---------------|---------------|--------------------------|------|-------|
| Steenkiste, Peter A - Sr. Research Comp. Scientist | 1.00 | | | 0.00 | 0.00 | 47918 |

SUMMARY PROPOSAL BUDGET Cumulative

| ORGANIZATION Carnegie-Mellon University | | | | FOR NSF USE ONLY | | |
|---|--|--|------|---------------------------------|------------------------|-----------------|
| | | | | PROPOSAL NO. | DURATION (months) | |
| PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR Brad A Myers | | | | AWARD NO. | Proposed | Granted |
| | | | | | NSF Funded Person-mos. | |
| A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets) | | | | CAL | ACAD | SUMR |
| 1. Brad A Myers - Sr. Research Scientist | | | | 2.40 | 0.00 | 0.00 |
| 2. Diana M Bajzek - Sr. Multimedia Consultant | | | | 2.40 | 0.00 | 0.00 |
| 3. Ruth W Chabay - Sr. Research Scientist | | | | 0.00 | 0.00 | 1.00 |
| 4. Sara B Kiesler - Professor | | | | 0.00 | 0.00 | 1.00 |
| 5. Joel M Smith - Director Technology in Educati | | | | 1.80 | 0.00 | 0.00 |
| 6. (1) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE) | | | | 1.00 | 0.00 | 0.00 |
| 7. (6) TOTAL SENIOR PERSONNEL (1 - 6) | | | | 7.60 | 0.00 | 2.00 |
| B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS) | | | | | | |
| 1. (0) POST DOCTORAL ASSOCIATES | | | | 0.00 | 0.00 | 0.00 |
| 2. (3) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.) | | | | 12.00 | 0.00 | 0.00 |
| 3. (6) GRADUATE STUDENTS | | | | | | |
| 4. (0) UNDERGRADUATE STUDENTS | | | | | | |
| 5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY) | | | | | | |
| 6. (0) OTHER | | | | | | |
| TOTAL SALARIES AND WAGES (A + B) | | | | | | 1,410,912 |
| C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS) | | | | | | 0 |
| TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C) | | | | | | 467,156 |
| D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING \$5,000.) | | | | | | |
| \$ 100,440 | | | | | | |
| TOTAL EQUIPMENT | | | | | | 1,410,912 |
| E. TRAVEL 1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS) | | | | | | 138,402 |
| 2. FOREIGN | | | | | | 0 |
| F. PARTICIPANT SUPPORT COSTS | | | | | | |
| 1. STIPENDS \$ _____ | | | | 0 | | |
| 2. TRAVEL _____ | | | | 0 | | |
| 3. SUBSISTENCE _____ | | | | 0 | | |
| 4. OTHER _____ | | | | 0 | | |
| (0) TOTAL PARTICIPANT COSTS | | | | | | 0 |
| G. OTHER DIRECT COSTS | | | | | | |
| 1. MATERIALS AND SUPPLIES | | | | | | 0 |
| 2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION | | | | | | 13,227 |
| 3. CONSULTANT SERVICES | | | | | | 0 |
| 4. COMPUTER SERVICES | | | | | | 179,701 |
| 5. SUBAWARDS | | | | | | 0 |
| 6. OTHER | | | | | | 34,117 |
| TOTAL OTHER DIRECT COSTS | | | | | | 227,045 |
| H. TOTAL DIRECT COSTS (A THROUGH G) | | | | | | 2,994,602 |
| I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) | | | | | | |
| TOTAL INDIRECT COSTS (F&A) | | | | | | 1,115,913 |
| J. TOTAL DIRECT AND INDIRECT COSTS (H + I) | | | | | | 4,110,515 |
| 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) | | | | | | \$ 4,110,515 \$ |
| M. COST SHARING PROPOSED LEVEL \$ 0 | | | | AGREED LEVEL IF DIFFERENT \$ | | |
| PI / PD TYPED NAME & SIGNATURE* | | | DATE | FOR NSF USE ONLY | | |
| Brad A Myers | | | | INDIRECT COST RATE VERIFICATION | | |
| ORG. REP. TYPED NAME & SIGNATURE* | | | DATE | Date Checked | Date Of Rate Sheet | Initials - ORG |

Budget Justification Page

PERSONNEL COSTS

Salaries: All salaries are based on 1999-2000 salaries. Faculty and staff salaries reflect an anticipated annual increase effective July 1. This incorporates merit increases as well as cost of living and market condition considerations. Graduate support is increased effective September 1. The colleges each set their graduate support rates in consultation with their faculty, department heads, deans and the Provost, taking into account an evaluation of our historical market position in comparison to our peer institutions. Salaries for research faculty and staff are based on a twelve month calendar year; salaries for teaching faculty and graduate students are based on a nine month academic year and three summer months.

Faculty and Staff Increase Rate: 3.50%
Average Graduate Support Increase Rate: 5.00%

Category B2 - Other Professional represents a Research Programmer.

Fringe Benefits: The University's fiscal year is July 1 - June 30. Fringe benefits for faculty and staff are calculated as follows. No fringe benefits are calculated on graduate student stipends or undergraduate student wages.

CMU fiscal year 2000 22.50%
CMU fiscal year 2001 23.60%
CMU fiscal year 2002 23.85%
thereafter 24.15%

OPERATING EXPENSES

General operating expenses are increased annually based on an estimate of inflation.

Operating Expense Increase Rate: 3.00%

Expenditures budgeted under operating expenses for this proposal are costs that can be identified specifically with this particular sponsored project and are required in the direct performance of the research. Some of these expenses can be estimated with a high degree of accuracy for this project and are listed individually. Other expenses are estimated using a formula. These expenses include applicable computer supplies and software, copying, telephone and fax toll charges, postage and express mail, technical supplies and printing expenditures. These proposed expenses are based on the following percentages of research salaries and fringe benefits.

Copying/Publications 0.28%
Long Distance Telephone 1.34%
Postage 0.24%

These percentages were derived from a comparison of 1998-99 expenditures to 1998-99 research salaries and fringe benefits. Since we round to the nearest dollar monthly, on a project basis, these expenses may not be exactly equal to the percent times the salary dollars. Copying/Publications and Postage charges are combined under category G2. Category G6 represents Long Distance Calls.

Budget Justification Page

TRAVEL

Travel has been estimated based on sample flight costs and daily expense rates for general east or west coast destinations. Detailed budget support is included on a separate attachment. These trips will include travel to sponsor's sites and scientific conferences (not yet determined) relating to this research effort. These travel amounts are calculated based on a sampling of typical trips taken by members of the department this past fiscal year and are increased at the same rate as operating expenses based on an estimate of inflation.

Travel costs using personal vehicles are calculated at \$0.30/mile. Airfare costs are based on average present costs, unless a destination is specified. Daily domestic expenses are calculated at a rate of \$102 per day for food expenses, ground travel including car rental and miscellaneous expenses. Nightly expenses are calculated at \$94 per night for hotel accommodations.

The project will require five project personnel to travel on two East Coast (3 days/2 nights) and two West Coast (4 days/3 nights) trips per year.

COMPUTING SERVICES

Included are technical and facilities maintenance costs. The School of Computer Science maintains its own computing facility and is not dependent on the university maintained facility. Included in the maintenance costs of our facilities are the costs associated with networking, systems software support, time-shared machines, printing, maintenance contracts and salaries of the facility staff, including computer operators, systems programmers, systems engineers, line technicians and repair technicians. Facilities maintenance costs in the School were found to be 7.06% of research personnel and fringe benefits costs in fiscal year 1998-99.

OVERHEAD

Overhead on this proposal has been calculated at our current proposed or negotiated rate for all fiscal years in accordance with OMB Circular A-21, Section G.7. The modified total direct cost base (MTDC) amount used in calculating the indirect costs is the total direct costs, excluding capital equipment, 50% of graduate student compensation, and individual subcontract costs in excess of \$25,000.

Overhead Rate: 50.60%