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Research in Industrial Projects for Students: A Unique Undergraduate Experience

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The Institute for Pure and Applied Mathematics at UCLA, with support from The National Science Foundation (NSF), The National Security Agency (NSA), and its industry sponsors has offered the Research in Industrial Projects for Students (RIPS) program every summer since 2001.

The mission of the Institute for Pure and Applied Mathematics (IPAM) is to promote and facilitate cross-disciplinary connections between a broad spectrum of mathematicians and scientists, to launch new collaborations, to better inform mathematicians and scientists about interdisciplinary problems, and to broaden the range of applications in which mathematics is used. IPAM holds programs throughout the academic year for junior and senior mathematicians and scientists who work in academia, the national laboratories, and other private or public organizations, as well as for students.

The RIPS Program was modeled after The Math Clinic at Harvey Mudd College, part of Claremont Colleges. Unlike conventional mathematics education where students typically solve problems independently, it emphasized a more structured and personalized team format to enhance the research training experience. RIPS features the same concept in a 9-week format.

In RIPS, undergraduates work in teams on a research project formulated by a government or industry sponsor in consultation with IPAM. Each RIPS team is comprised of four students, a faculty mentor, and one or several industry mentors. During the nine week program, the students study the problem and master the latest analytical approaches and techniques to solve it. The students also develop the report-writing and public-speaking skills needed to present their work to a scientific audience. Industry mentors provide regular contact between the team and the sponsor, while monitoring and helping to guide student work. Participation in RIPS provides valuable real-world technical and managerial experience for students and valuable R&D for sponsors.

Recruitment and Selection of Students

IPAM makes extraordinary effort to promote RIPS, especially to women and to underrepresented ethnic groups. An announcement is submitted to national organizations and journals. A poster advertising RIPS is distributed at IPAM events,

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national conferences (Society for Advancement of Chicanos and Native Americans, Historically Black Colleges and Universities, etc.), and professional meetings. IPAM board members assist in distributing information. We send emails to mathematics faculty, student advisors, and undergraduate club officers across the country. Undergraduate engineering and computer science advisors are also routinely included in mailings. A poster promoting RIPS to young women is disseminated widely. Finally, all past participants of RIPS are asked to help promote RIPS to undergraduate students at their institutions. Word of mouth is probably our most successful means of recruitment.

RIPS students are academically in the top tier of their class. While an extensive mathematics background is a prerequisite for selection, the RIPS students represent a wide range of backgrounds and academic pursuits. For example, while the majority of the RIPS 2006 participants were mathematics majors, a number of them studied computer science, electrical engineering, physics, and computational biology. The group also represented a variety of institutions, including prestigious technical colleges (Caltech, MIT, RPI), Ivy League schools (Yale, Harvard, Princeton), other liberal arts colleges (Gettysburg College, Carleton College), and public universities (UCLA, San Jose State, North Carolina State). Most of the students were rising seniors or 2006 graduates.

Applications are due mid-February. The IPAM directorate initially screens the applications for general suitability. A subset of the total applications is then presented to each industrial sponsor, which then assigns grades to each applicant to indicate their preferences and needs of the project. The directorate then considers industry sponsor preferences as well as other goals for RIPS participation to make final selections. In the event that a student declines the invitation to participate, alternates are also chosen. The goal is to put together teams whose members have the appropriate combination of skills and experience for the proposed project.

The selection process is highly competitive. Out of 225 applicants for RIPS 2006, only 36 students (16%) were ultimately chosen to participate. The competition for high-achieving minority students is always quite high; nevertheless, we were pleased that four students who are members of underrepresented groups did participate. We were also delighted at our success at recruiting women. See Table 1.

Table 1: RIPS 2006 Participants

	Total	Female		Male		Members of Underrepresented Groups	
Student Participants	36	14	39%	22	61%	4	11%

Interested students may (and often do) apply again if they are not chosen the first year they apply. Due to demand for RIPS, we do not allow a student to participate in RIPS twice, although many express a desire to do so.

IPAM Directorate

IPAM Director Mark Green is largely responsible for the scientific content and operation of RIPS. Director of Special Projects Stanley Osher and Associate Director Christian Ratsch assist Dr. Green with student selection, recruiting industrial

sponsors, reviewing the Sponsors' project descriptions, and identifying and recruiting faculty mentors.

Program Director

Michael Raugh, retired Professor of Mathematics at Harvey Mudd College and cofounder of Interconnect Technologies Corporation, has served as the RIPS Program Director each summer. The Program Director duties include weekly meetings with faculty mentors and project managers to provide support and guidance, reviewing each team's reports and presentations, and active participation in Orientation Day and Projects Day.

Faculty Mentors

One faculty mentor is assigned to each team. Faculty mentors are typically recently graduated post-doctoral scholars in mathematics or other relevant disciplines. They provide methodological guidance, review and critique work, offer encouragement, support, and sometimes career counseling and advice. Some have returned for a second or third year because they enjoy working with RIPS students.

Sponsors and Industry Mentors

RIPS sponsors represent industries in the government and private sectors, such as biotechnology, computer animation, and anti-virus software development. All are engaged in research and development in leading-edge technologies that require advanced mathematics knowledge and skill. Sponsors are typically recruited through IPAM's scientific programs. IPAM invites prospective sponsors to RIPS Projects Day (see RIPS Schedule, below) to demonstrate the impressive outcomes of current projects. See table 2 below for a list of RIPS 2006 sponsors.

Sponsors are intimately involved with the design of projects and selection process. During the program, the team's industry mentor or team of mentors representing the sponsor meet with their team weekly either in person or by telephone conference call if the sponsor is not local. All industry mentors attend Orientation Day and Projects Day. In addition, the sponsor hosts the team for at least one site visit.

Many organizations are serial sponsors. IPAM recruited two new sponsors in 2006 (see table 2), and is in conversation with several private companies and a state agency about sponsoring RIPS projects in 2007 or 2008. IPAM will continue to seek out new industrial sponsors with interesting projects, as well as retain the ones that have participated in the past.

Projects

RIPS projects are carefully designed to challenge students and expose them to a range of mathematical theories and concepts relevant to the project. For example, the Symantec team's project in 2006 involved the use of image compression algorithms to identify image variants found in spam. See Table 2.

Prior to the start of the RIPS Program, each industrial sponsor prepares a Project Description explaining the problem. The statements are written by the sponsor in consultation with the faculty mentor and IPAM directorate.

Table 2: RIPS 2006 Sponsors and Projects

Sponsor	**Title of Project**	**New/ Returning**
Areté Associates, Inc.	Video Images Mapping and Compression for Efficient Data Downlink	Returning
Hewlett-Packard, Inc.	Procurement Is Possible	Returning
Jet Propulsion Laboratory	Impulsive Low Energy Transfers Between the Earth and the Moon	Returning
Los Alamos National Laboratory	Robotic Path Planning and Visibility with Limited Sensor Data	Returning
Lawrence Livermore National Laboratory	The Disambiguation Problem	Returning
NASA Goddard Space Flight Center	Methods for Detecting Gravitational Wave Signals in LISA Data	New
Pixar Animation Studios	Simulation of Many Colliding Deformable Solids for "Set Dressing" and Arrangement	Returning
Symantec Corp.	Image Similarity for Detecting Image-Based Spam and Phishing Attacks	New
TimeLogic, Inc.	Determining the Sequence of Peptides from Tandem Masspectra	Returning

RIPS Schedule

RIPS begins with Orientation Day, at which students are introduced to the structure and expectations of the program and have the opportunity to discuss their Project Description with their industry sponsors.

Shortly thereafter, the students prepare a work statement, a contract between the student team and sponsor, which is forwarded to the industrial sponsor for approval or negotiation. Once completed, the team begins its research and conducts regular meetings with its industry mentor and faculty mentor. Each team also selects one student to act as project manager.

During the fourth week, each team presents their project findings to date and submits a brief mid-term report to the Program Director. Faculty mentors and industrial sponsors provide feedback and direction. Throughout the next few weeks, each team visits their industrial sponsor's site, often to present their research to a group working on similar problems.

On Projects Day, held at the end of the eighth week of the program, each team gives a professional-quality slide presentation of their work. Industrial sponsors, faculty mentors, UCLA mathematics faculty and graduate students, prospective industrial sponsors, and some family members of RIPS participants typically attend. The students also begin preparing their final reports.

During the ninth week, final revisions are made to the reports which are then carefully reviewed by faculty mentors and the Program Director. The report and slide presentation are sent to the sponsor upon completion. On the last day of the program, students "graduate" from RIPS and receive a certificate of participation.

Impact and Results

In five years, RIPS has become a highly selective program. It began in 2001 with 43 applications, 12 students and four projects. By 2006, RIPS received 225 applications for 36 openings and 9 projects. Our recruitment of women in 2005 and 2006 was particularly successful, representing approximately 40% of total participation each summer. While recruiting members of underrepresented ethnic groups continues to be a challenge, we have achieved a participation rate of 11% to 12.5% for the past three years.

The number of projects each summer has gradually expanded from four to nine, demonstrating our ability to recruit and retain sponsors as well as the increased demand for the program. We are pleased with the mix of private companies and national labs and with the quality of the prospective new sponsors for 2007 and 2008. Many of the sponsors return to participate multiple times; in fact, four industrial sponsors have participated for four or more consecutive summers through 2006. The projects that they propose are of high quality, challenging the students yet presenting a problem that is appropriate for a nine-week undergraduate program.

The quality of the students' work is impressive. Sponsors have been pleased with the results, and have consistently praised the program in our closing survey. Here are some comments from past industry mentors:

- Peter Eltgroth and Peter Brown, LLNL, RIPS 2002 and 2004: "I was impressed by the quality of the students, not just in terms of their credentials coming into the program, but by what they produced, as undergraduates, over the course of two months ... The final report for this project is a remarkable piece of work that benefits us here at LLNL."
- Terence Kelly, HP Labs, RIPS 2006: "RIPS was a very rewarding experience for us as industrial sponsors. Our team shed new light on known aspects of our problem. More importantly, our team discovered new aspects of the problem and suggested new directions for future research."

Many students tell us that RIPS had a significant influence on their decisions about graduate school and attitude towards math and industrial research. Here are a few quotes from RIPS students that demonstrate the immediate and profound ways the program impacts its students:

- Jennifer Garcia, RIPS 2001: "If it were not for IPAM and a small list of caring professors, I would never have learned of my passion for research."
- Jason Geertz, RIPS 2002: "After attending the IPAM program RIPS 2002, I decided to attend graduate school and continue with research. I believe my experience there taught me a lot about managing and doing scientific research."
- Jacob Macke, RIPS 2004: "[RIPS] has greatly strengthened my resolve to pursue a career in academia, and I will embark on graduate studies in computational neuroscience next year. I have plenty of offers to choose from ... and am convinced that without RIPS at IPAM, I would not have been able to achieve this."
- Lisa McFerrin, RIPS 2004: "My IPAM experience was a huge motivator to my current situation. I was placed in the BioDiscovery group and was introduced to the field of bioinformatics. I loved the ideas that we were working with and the implementation process which coincided exactly with my expertise and interest."

The impact of RIPS on undergraduate student academic and professional careers is broad. For some students, RIPS opens doors to graduate study, for others to new career pathways, and for still others, the possibility of job opportunities with an industrial sponsor. Here is a sample list of achievements of past RIPS students, directly or indirectly resulting from their participation in RIPS:

- Miranda Lee (RIPS 2001), now a graduate student at Stanford, won National Defense Science and Engineering Graduate (NDSEG), National Science Foundation (NSF) and Stanford Graduate Fellowships.
- Dan Shaevitz (RIPS 2002) began working at Areté Associates as a Research Analyst after participating in RIPS.
- Two of the four students on the 2002 LLNL team went on to pursue their graduate studies in Computational Transport at Princeton and the University of Colorado at Boulder.
- Two RIPS students on the LANL team (from different summers) subsequently completed LANL internships.
- Linda Hung (RIPS 2003) participated in the Cryptanalysis and Exploitation Services program at NSA the following summer. She then entered the PhD Program in Applied Math at Princeton.
- Che Smith (RIPS 2004), an African-American woman from Spelman College, was accepted to graduate school in Biostatistics at Harvard, UCLA, and North Carolina State.
- Jeff Aristoff (RIPS 2004) says that his participation in RIPS helped him obtain an NSF Graduate Research Fellowship in applied mathematics.
- Lauren Anderson (RIPS 2004) has since completed an internship with Northrop Grumman, which offered her a position after she graduates.

RIPS also influences the careers of its faculty mentors. For example, four-time RIPS faculty mentor Shawn Cokus, who had a background in combinatorics and knew no biology when he was selected to mentor a RIPS bioinformatics projects, now has a job working in a bioinformatics lab at UCLA.

Finally, IPAM has offered its support and materials to those who wish to replicate RIPS at their own institutions. Several interested faculty attended 2005 and 2006 Projects Day to see first-hand the final products of the student teams.

Future Plans

IPAM is pleased with the success of RIPS and intends to continue running the program for the rest of IPAM's current NSF grant, which continues through 2010. We will maintain the current size of the program: 9 projects and 36 students.

At the same time, we will expand RIPS by offering RIPS-Beijing in 2007. Dr. Harry Shum, Managing Director of Microsoft Research Asia (MSRA), has agreed to host five RIPS projects at their Beijing facility. Ten US students and ten Chinese students will work in teams of four (with two members from each country) on five projects sponsored by MSRA research groups. The idea is to integrate an international research experience with the RIPS concept. IPAM recently applied for an International Research Experiences for Students (IRES) grant through NSF to support the U.S. participants of this program.

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