



SURF 2004 is dedicated to Dr. Harry Gray, Arnold O. Beckman Professor of Chemistry and Founding Director of the Beckman Institute, in recognition of his enthusiastic support of the program over the past 25 years; his commitment to excellent research opportunities for our outstanding students; his continued active participation as a mentor and good friend of the program; and for his valuable assistance in helping to secure a home in the Beckman Institute for the program. Professor Gray has mentored 53 students and has been an exemplary role model for his protégés. We are proud to dedicate SURF to Professor Gray!

SURF has been dedicated to the following people:

1985 Dr. Ernest Swift
1986 Dr. Lee A. DuBridge
1987 Dr. Robert P. Sharp
1988 Dr. Ray D. Owen
1989 Dr. Hans W. Liepmann
1990 Dr. Fredrick H. Shair
1991 Dr. Lew Allen Jr.
1992 Dr. John D. Roberts
1993 Dr. Robert E. Bacher
1994 Dr. Edward C. Posner
1995 Mr. Samuel P. Krown
1996 Dr. Edward B. Lewis
1997 Dr. Harold Brown
1998 Dr. Thomas E. Everhart
1999 Dr. Ward Whaling
2000 Dr. Terry Cole
2001 Dr. William Whitney
2002 Dr. Edward C. Stone
2003 Dr. Thomas A. Tombrello, Jr.
2004 Dr. Harry B. Gray



David Baltimore

to **ENGAGE** in **RESEARCH**

President's Message

As an undergraduate at Swarthmore, I had the remarkable opportunity to do research one summer with George Streisinger at Cold Spring Harbor Laboratory through an NSF-funded program. I discovered that doing research was much more interesting and educational for me than taking classes. Dr. Streisinger was an excellent mentor, spending time, talking with me about biology, and introducing me to renowned biologists who spent their summers at the laboratory. That undergraduate research experience shaped my decision to become an experimental biologist.

My experience was not unique. I am convinced that most students learn best when they can *do* science or engineering rather than just study it in the classroom, and the SURF program offers our students the extraordinary opportunity to engage in research with mentors who work at the frontiers of their fields. The students experience the life of scientists and engineers while mentors and other members of the research group welcome them into the community of researchers and scholars. Students take intellectual ownership of a project as they explore the secrets of nature, learn to ask questions, persist in the tedious, often repetitious, details of experiments, and sometimes experience the joy of discovery.

They learn, too, what careers they want, or don't want, to pursue.

SURF depends upon the financial, personal, and professional investment of hundreds of individuals. I am deeply grateful to those who support the SURF program: donors—individuals, foundations, and corporations; mentors—Caltech faculty and JPL technical staff; co-mentors—graduate students and postdoctoral scholars who often assume day-to-day supervision of the students; alumni for their personal interest and involvement with the program; volunteers—faculty, graduate students, postdoctoral scholars, and others—who review proposals and reports or assist with SURF activities and events; and the Institute staff who ensure the smooth operation of the program.

Caltech is a singular institution, a world leader in research and education, and SURF is one of the programs that keeps the Institute at the forefront. Caltech's capital campaign seeks to raise \$10 million for the SURF endowment over the next three years, and I hope you will consider a generous contribution to this outstanding program. Your partnership with the Institute and SURF ensures that our students will always enjoy these rich opportunities and gain the advantage of working with world class mentors.

John Gee

Once again, SURF has completed an outstanding year with a total of 408 SURF students, 264 of them from Caltech, working with 210 mentors on the campus and at JPL. In addition to SURF, the Student-Faculty Programs Office coordinates four other programs bringing the total student contingent to 516. This represents an increase of 18% over last year. SURF, together with the related programs, makes Caltech the best of summer undergraduate research programs, and helps the Institute remain one of the most attractive universities for top students interested in science, engineering, and research.

SURF 2004 is dedicated to Professor Harry Gray, Arnold O. Beckman Professor of Chemistry. Professor Gray has been a supporter of SURF since its early years, and with his group of co-mentors and eight SURF students, exemplifies the strength of Caltech's SURF program—the collaborative effort of faculty and students working

From the SURF Board

together. Our thanks go out to the Gray Group for providing outstanding mentoring and guidance to 53 SURF students since 1981.

I am delighted to announce that Mr. Carl Larson, Caltech alumnus and Life Member of the SURF Board, has agreed to chair the SURF Board Development Committee. Other members include Mr. Kirk Dawson, Mr. John Glanville, and Dr. Jim Cutts. The committee will continue to work closely with the Development Office to explore avenues of cooperation and assistance in raising the \$10 million addition to the SURF endowment as part of *There's Only One Caltech* campaign.

I extend the gratitude of the SURF Board to Mrs. Margaret Leighton for creating the Thomas Lauritsen SURF Endowment this year and to Mr. and Mrs. Kirk Dawson for designating a SURF endowment in their estate plan. We are very pleased that alumni have increased contributions to SURF and heartily thank them. All these gifts represent significant progress toward reaching our endowment goal though the challenge remains great.

The new member of the SURF Board for the coming year is Mr. Duane McRuer (BS '45, MS '48). Re-elected members include Ms. Gabrielle Adelman (BS '87, SURF '85, '86), Ms. Karen Carlson (Caltech Alumni Association), Dr. Jim Cutts (BS '54), and Mr. Sam Vodopia (BS '54).

Mr. Sean Upchurch and his committee (Dr. Michael Hartl, Ms. Leslie Maxfield, Dr. Carel Otte, and Ms. Adele Shakal) continue to recruit moderators for SURF Seminar Day. In addition to increasing the number of moderators, they have arranged for last-minute help for students with their talks and created an introductory background program for visiting high school students.

Carolyn Ash and her Student-Faculty Programs Office staff keep the SURF program running very smoothly and have accommodated the growth of SURF and the allied programs without a hitch. Carolyn has been the heart of the administration of SURF almost from the beginning. On behalf of the SURF Board, we salute you and your staff for your outstanding efforts for SURF.

Most importantly our thanks go to the mentors and co-mentors for their steady support and participation that makes SURF at Caltech possible and such a great opportunity for the students.

As Chair of the SURF Board, I want to thank the Executive Committee (Carel Otte, John Glanville, Fred Shair, and Carolyn Ash) and all of the members of the Board for their support. I know that we all look forward to the coming year and to working together for the benefit of SURF.

ANOTHER great SURF summer...

SURF Administrative Committee

The SURF Administrative Committee provides faculty oversight of the academic and research aspects of the SURF program. It ensures quality of the program by reviewing students' proposals and making recommendations for SURF awards, maintaining interactions with SURF mentors, and providing counsel to the Director of Student-Faculty Programs. The AdComm establishes program policy, is responsible for long-range planning, and reviews new programs related to SURF.

There were 686 applicants for SURF 2004 of which 415 (61%) were accepted; four students declined the awards and three

other students withdrew before the end of the program leaving a total of 408 students (or 59% of those who applied) who completed SURF 2004. Of the 408 SURFers, 264 (65%) are Caltech students. There were 144 (35%) non-Caltech students. The AdComm voted to limit the non-Caltech participation to 25% a few years ago, but that was before the exchange programs came into effect and before MURF became part of the Student-Faculty Programs Office. Of the 408 SURFers, 15 were JPLUS students drawn from 15 of the 30 community colleges participating in JPLUS. JPL had 68 SURF students of which 26 (38%) are Caltech students. The SURF contingent also includes 31 MURF students (8% of the total SURF class).

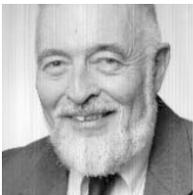
SURF initiated online applications this year making the process of submitting and reviewing applications and proposals much more efficient and effective than it had been under the paper system. The software went up with few "bugs," the students appreciated the improvement, and the reviewers were very satisfied with the ability to read and comment on applications via their computers anywhere in the world.

As more graduate students and post-doctoral fellows become more involved in the day-to-day (or hour-to-hour) mentoring, the mentoring workshop conducted at the

beginning of SURF has proven to be quite helpful to new co-mentors.

Throughout the years, many individuals with insight and dedication have added new dimensions to the SURF experience. This year the Monday Evening Professional Development Workshops have been appropriately renamed the William Whitney Workshops in recognition of Bill's initiation and implementation of them 14 years ago and in appreciation for his hard work coordinating them each year.

Congratulations to the 2004 SURFers and their mentors for an extraordinary summer. We deeply appreciate the support and loyalty of the members of the SURF Board, the SURF Administrative Committee, the SURF Student Advisory Council, and the Co-Mentor SURF Advisory Council. We depend upon and thank the donors who make SURF possible with their generous gifts, and the many other individuals who support and encourage the SURF students through their volunteer participation in the program. Finally, we thank the staff of the Student-Faculty Programs Office under the wise, consistent, and dedicated leadership of Carolyn Ash for another great SURF summer!



Fred Shair

Galen Loram

SURF Student Advisory Council

The Summer Undergraduate Research Fellowships—Student Advisory Council (or SURFSAC, in order to spare a mouthful) is a group of about a dozen students who serve the Student-Faculty Programs office in making sure that the SURF experience is not only intellectually challenging and interesting, but is enjoyable as well.

Towards this goal, the students of SURFSAC help welcome non-Caltech students to the houses and try and help resolve the inevitable cultural conflicts that occur. Bringing 250 students from other colleges and universities across the country into the intimate culture of the student houses is sure to not be a perfectly smooth integration, so SURFSAC helps to make the newcomers feel welcome, as well as encourage the Caltech students to meet and mingle with the non-Tech students. In the end it seemed to be successful. At the end of SURF, I had more than a dozen students—both Caltech and non-Caltech—randomly tell me that they had really enjoyed their experience here and had met some incredible people. Social groups and friendships that would not have formed during the year flourish during the summer, and many of them carry over into the regular school year.

The other major role of SURFSAC is to serve as something of a “social team” over the summer. From organizing weekly Frisbee or Capture the Flag games to an expedition to see fireworks for the Fourth

of July, the SURFSAC group does their best to make sure that there are interesting things going on around campus. This is especially important for visiting SURF students who don’t come with established groups of friends (and thus get a chance to meet new friends at these events), and aren’t familiar with the area. We also try to offer a chance to experience the ‘cultured’ aspects of Los Angeles—for example, a trip to the Getty museum and a series of eight dinners with professors at local restaurants (kindly funded by Cathy Jurca, the MOSH) were both a hit this year. We also offer students a chance to enjoy the unique geography of Los Angeles—a beach trip, a pair of hiking expeditions in the mountains of the Angeles National Forest, and a trip to the Goldstone Observatory in the desert piqued the interest of a number of students.

Special thanks go out to Shannon Lewis and Joy Rimchala, who went far above and beyond the call of duty. Shannon was involved in planning about a half dozen of the events and was the chief organizer for four of them. Joy coordinated all the SURFSAC Suppers and invited the faculty guests, coordinating their busy schedules.

Overall, the year was a resounding success. A big thank you to all the members of SURFSAC, for their time and dedication as well as to the members of the Student-Faculty Programs Office for their encouragement, support and funding—it wouldn’t have been possible without you.

SURF HISTORY

UNDERGRADUATE RESEARCH has a long history at Caltech. In the early '20s, Arthur Amos Noyes, a member of the Institute's founding triumvirate and first chair of Chemistry, made Independent Research (9 units) a graduation requirement for all chemistry majors. But only the very best undergraduates were able to compete successfully with graduate students in the intense competition for summer research jobs. There are no records, but an occasional publication co-authored by an undergraduate shows that the undergraduate applicant sometimes got the job (for example, in 1928, Assistant Professor Linus Pauling and senior Edwin McMillan, both of whom would go on to win Nobel prizes, coauthored a paper in the *Journal of the American Chemical Society*). It was only after WWII that federal research contracts made summer jobs for undergraduates more plentiful all across the campus. And these summer research jobs were for lab help, not independent research. It was not until SURF was founded in 1979 that Caltech had a campus-wide program to encourage any student to do independent research.

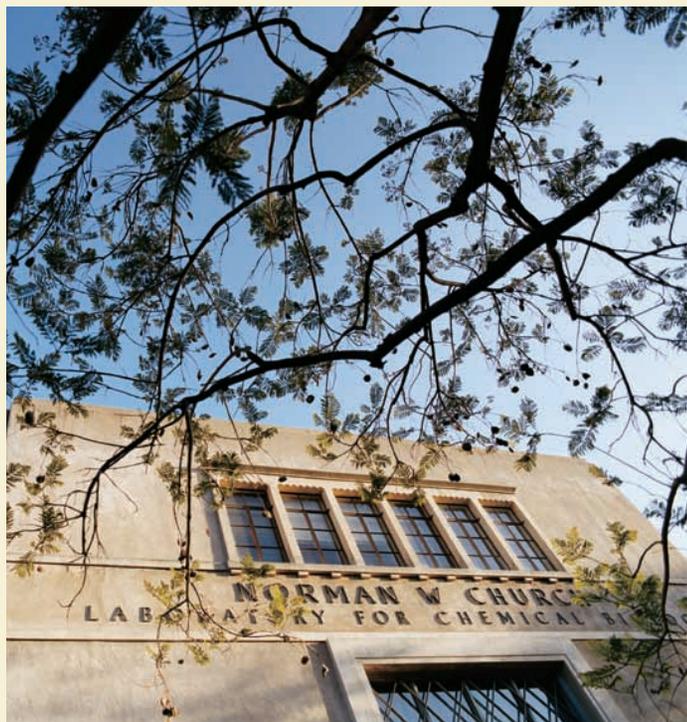
The SURF story really begins eleven years before its founding in 1979. Beginning in 1968, Caltech received funds from the Paul K. and Evalyn E. Cook Richter Memorial Funds to support various student projects. These funds had been established by their son, J. Edward Richter, "to enable leading educational institutions to provide opportunities for students to

work closely with faculty to promote individual achievement." In the mid-1970s, then President Harold Brown proposed to the trust officer that the Richter Funds be used to establish an Undergraduate Research Participation Program (URPP) that would meet the donor wishes and benefit Caltech students. A grant of \$12,000 was awarded to Caltech, and the funds were given to Professors Tom Tombrello and Richard Dean to support undergraduate research in physics and mathematics. After SURF was established, Professor Tombrello, with the agreement of the trust officer, directed the Richter Funds to support SURF students in physics. Shortly afterward, the Richter Funds awarded grants directly to the program, and since that time, the trust has contributed well over a million dollars and has supported close to 500 Richter Scholars. We salute the vision and leadership of the Paul K. and Evalyn Elizabeth Cook Richter Memorial Funds and its trust officers, currently Mr. Charles Slamar.

In 1978, Caltech Trustee Lew Wasserman established a prize scholarship fund to recognize student achievement in effective and imaginative ways. A faculty committee debated the ways to accomplish the donor's wishes, and Professor of Chemical Engineering Fred Shair proposed that, instead of a monetary prize, students be awarded a modest summer stipend and the priceless opportunity to work with a member of the Caltech faculty on an independent research problem that the two of



them had devised. Wasserman agreed to this unusual and original interpretation of the prize, and SURF was born. It grew explosively, first at Caltech and soon all over the country. Today a Google search for “SURF” turns up literally hundreds of campus, government, and industrial labs that offer summer undergraduate research fellowships.



The SURF endowment was established in 1982 with a \$50,000 gift from Samuel and Frances Krown. So far as we know, this is the first instance in any American university of an endowment dedicated to the support of undergraduate research. The principle has grown through the creation of 48 additional endowments and is now valued at \$5.9 million.

In 1999, the Western Association of Schools and Colleges recommended in its accreditation review that the Institute complete the SURF endowment and relieve the need for annual fund raising for student stipends. The Institute has taken the charge seriously, making SURF a priority in the current capital campaign with the goal of raising an additional \$10 million.

SURF’s modest beginning in 1979—18 students working with 17 faculty members on the campus—has expanded, matured, and continues to flourish with 408 students working with 210 mentors in 2004. In 1979, the stipend budget was \$36,000; in 2004 it was \$2 million. Non-Caltech students joined the SURF enterprise in 1983, and Caltech students often win SURF fellowships to collaborate with faculty at other institutions in the US and abroad. Enrichment activities have been added to enhance the students’ research experiences. But many things remain unchanged.

The core elements of SURF are the same as they were at the beginning. Students collaborate with mentors to define and develop a project prior to writing a

research proposal. A faculty committee reviews the proposals and SURF awards are made on the basis of reviewer recommendations and available funds. Students work on their projects over ten weeks in the summer, and at the conclusion they submit technical papers and give oral presentations.

The essence of SURF remains unchanged: Students collaborating with mentors welcomes undergraduates into the community of researchers and scholars. For a summer, students experience the life of a scientist or engineer; they gain insight into the careers they want to pursue and discover whether or not they want to attend graduate school. They learn the methods and techniques of research in their fields, how to ask questions and what questions to ask. They develop communication skills that will benefit them through their lives.

The vision and leadership of many individuals established the roots of undergraduate research at Caltech. The creation of SURF brought the possibility of doing research to all students. The generosity of a multitude of donors helped SURF to grow and mature, and the creation of the endowment has insured its future. SURF is now imbedded in Caltech’s culture and we look ahead to a bright future for our students who will become the technical leaders of their communities, the nation, and the world.

1.

(l to r) Mentor Richard Murray and Henrik Kjellander



The GRAND CHALLENGE

Serving as a mentor to a young scientist is an important role. Mentors pass on the nature and culture of science to the next generation and play a significant role in providing intellectual stimulation for their students. Sometimes the relationships formed through scholarly collaboration last long after the student completes his or her degree and ultimately develop into strong professional interactions. Mentors play a key role by providing advice, making observations, and giving feedback.

Mentors gain personal satisfaction from working with students. They often enjoy training the next generation, watching students mature intellectually, and knowing that they played an integral part in that process. Students can bring a fresh perspective to the work because they have not developed biases about what should or should not happen, and they might ask the simple questions that are often overlooked when one has been immersed in the research for a long time.

The mentor-student relationship is the SURF story. While the program offers enrichment activities—workshops, seminars, and social events—the heart of SURF is the apprenticeship of the students guided by their mentors.

It all began in March 2003 when Professor Richard Murray, Caltech alumnus (BS '85), Professor of Mechanical Engineering, and Division Chair of Engineering and Applied Science, issued the following message to Caltech undergraduate students:

Project description: DARPA (Defense Advanced Research Projects Agency) has set forth a grand challenge to develop an autonomous vehicle that can drive along a mixed on/off-road course between Los Angeles and Las Vegas in 10 hours or less (about 250 miles). The vehicle must be completely autonomous, including figuring out how to pick out a path (along a road, through an opening in a fence, or across a stream), reacting to events that occur along the course (eg, failure of sensors, presence of other vehicles), and refueling (you can cache fuel along the course, but humans can't be involved in transferring it to the vehicle). The course will be specified as a set of GPS waypoints with boundaries describing the allowable boundaries for the vehicle's trajectory. The first year of the competition is in March 2004 and the winning team gets \$1M.



(l to r) Lyle Chamberlain and Haomiao Huang

OVER THE COURSE OF A YEAR, a team of 23 undergraduates, including five 2003 SURF students, customized a vehicle, a 1996 Chevy Tahoe SUV named Bob (because of the alphabetic component of the license plate), and identified technologies to operate it autonomously for the DARPA Grand Challenge (DGC). On the day of the great race, the Caltech vehicle traversed 1.3 miles before it veered off the road to avoid an obstacle and broke through a barbed-wire fence. None of the other twelve entries completed the race either. DARPA doubled the prize money, and the effort to build the winning vehicle began again. This summer's SURF team of seven students builds on the previous efforts and prepares the way for the continuation of the project.

The DGC has become a research, educational, and professional focus for Caltech, and SURF is an integral part of the effort. This big project brings together students with different academic backgrounds to work together in teams to create the vehicle that will win the race. Murray says that, unlike a traditional SURF project where a student works on a project with a mentor, the DGC presents real engineering problems to be solved the way engineers work in the world. "The students have their own projects, but teamwork is essential to solve the problems, because the DGC requires too much infrastructure and a lot of systems

work. The students have been put into teams to identify the technologies we ought to spend next year working on," he says. Through participation in projects like this, students discover what graduate school will be like. They also have to learn things on their own because the problems they get in a SURF are not the ones they get in class. "Experiential learning is very important," Murray says.

Joel Burdick, Professor of Mechanical Engineering and Bioengineering and co-mentor of the SURF DGC group, describes the team structure. The Vehicles Team is responsible for the physical implementation of the racing vehicle, maintenance, design and specification, and modeling of the vehicles; the Imbedded Systems Team works on the software guts of the vehicle; and the Planning Team develops the high level "smarts" of the vehicle. The Documentation Team makes sure that everything gets put on paper. All the teams have to work together, and that is an interesting management project in itself since the students come in with different backgrounds, at different levels, and with different objectives.

Elliott Andrews, retired Engineering and Applied Science Division Administrator whose hobby is rebuilding cars, works with the Vehicles Team. This summer Elliott and James Allington, MURF student and a junior mechanical engineering major from the University of

California at Irvine, rebuilt Homer, a small off-road vehicle used to test components that will eventually be used on the race vehicle. Homer is much easier to start and drive around; it can be operated on campus; and it doesn't take a truck and trailer to take it to where it can be tested as Bob does. "We have to move heaven and earth to get Bob viable and running for a test. Each day takes hours, money, and space; we can't do it easily. So Homer is very important in this project," explains Elliott.

Homer had been purchased second hand. "The motor was blown, the electrical system didn't work, the frame was broken, and it was rusted," says Elliott. He and James took Homer apart down to the last nut and bolt and put it all back together in order to make it a safe and reliable vehicle which will be used for the next 15 months.

Coming from UC Irvine, James was not familiar with the project and questioned every decision the DGC team had made in the last year. "We had to explain and excuse and justify. He questioned things about Bob and about Homer. James learned a lot, and we clarified our thinking. Sometimes he was right and sometimes we were. It was a good way to reexamine the decisions we had made," observed Elliott.

James says, "This is my first time working on this project, and it has been as much fun as I expected. The biggest



James Allington

surprise to me is the level of organization required for such a large group effort. The team has been very effective in working together towards our common goal.” He finds the experience rewarding and educational and it has confirmed his interest in attending graduate school, perhaps at Caltech.

Henrik Kjellander, a computer science major from Lund Institute of Technology in Sweden, has been working on improving the arbiter, the “brain” of the planning system for the vehicle. He explains that the arbiter gets input from all the other systems (sensors, vehicle state, waypoint following) and then decides where the vehicle should go. “I’ve also been creating a simulation system to do real testing. I wrote a program to communicate between our current software and a simulation engine called Gazebo.” Asked how he got interested in this particular project, he responded, “After looking at the website, there was no doubt about how cool this project is!”

Haomiao Huang, a Caltech junior and EE major, worked on the DGC all last academic year developing the GPS/inertial navigation system for Bob, but this summer he is working on Peggy, a subscale test platform for developing high-speed driving control techniques. “I expected a lot of fun and a lot of work, and so far both those expectations have been met. We’re finally close to getting some results, so I’m getting really excited,” he says. “Much of this summer has been spent getting hardware up and run-

ning. Now we’re getting into the real research part of the project, and it’s been awesomely exciting to see the data from our runs.”

Asked what the experience has been like for him, Haomiao replies, “Wow! So much to say. I’ve probably learned more from working on the DGC than doing anything else at Caltech, and it was immensely satisfying to see Bob driving off on its own the first time. Now we’re going on to the second generation, and I’m very excited about what we’re doing. It’s a really great chance to learn something and actually apply it, as opposed to just doing problem sets or writing up a paper and never touching the subject again.”

Jeremy Gillula, a sophomore majoring in computer science, works on all things related to cameras including maintaining, focusing, and calibrating the stereovision and road-following cameras as well as ensuring the cameras have adequate interfaces to the software. He says that working the DGC

is like being at Caltech—fun, and a lot of work. He has learned much about working on a large team, integrating different fields. He knows professors better and has gotten a glimpse into what it is like to be a graduate student.

Both Murray and Burdick rely on their graduate students and postocs to assist with mentoring their SURF students. The co-mentors generally plan on an academic career, so it is an opportunity to help the co-mentors learn how to coach students. They meet with their students weekly when they all discuss their work, listen to what others are doing, problem solve, and figure out where to go next.

Murray and Burdick hope to have a large DGC SURF team next summer. The DARPA Grand Challenge presents excellent opportunities for students to immerse themselves in interesting engineering problems, apply what they have learned in the classroom to a project, invent new technologies, and in the end produce the winning vehicle and collect the prize money. Go Team Caltech!



Chua



Gillula



Allington



Kjellander



Chamberlain

2.

SURF stories

(l to r) Mentor Harry Gray and Mallori Watson



The GRAY GROUP





Harry Gray SURF Fellow Nicholas Halpern-Manners

HARRY GRAY, Arnold O. Beckman Professor of Chemistry and Founding Director of the Beckman Institute, leads a research group that includes eight SURF and MURF students this summer, bringing the total number of SURF students he has mentored to 53. He is an energetic and supportive mentor who encourages his students in many ways. “Some students need confidence. They might need to work on something simple so they succeed and gain confidence. Other students are like grad students or postdocs and are able to take on a problem independently. I think mentoring is really understanding that and being able to adjust to the situation,” he says.

Harry, as he is known to almost everyone, works closely with SURF student Patrick Hummel, a sophomore majoring in applied and computational math, on a project in ligand field theory that Harry worked on 40 years ago at Columbia. A Dutch research group recently recalculated the original findings and suggested a different result.

PATRICK IS LOOKING AT THEIR RESULTS with the latest calculations and agrees with the Dutch group findings; however he expanded the project to include a number of other carbon monoxide complexes. Patrick and Harry are writing a paper to confirm that they have reassessed the early work and agree with the Dutch group’s reinterpretation. “Until we do that people will think there is controversy. In sci-

ence you are continually correcting old work,” says Harry. “I think Patrick has been successful. It is such a short time, 10 weeks, but I think we will get two papers out of this project.”

Patrick did his first research at Caltech as an Axline SURF student, one of a select group of admitted students offered the opportunity to do a project prior to freshman year, and this is his third SURF. He says, “I have enjoyed all the SURFs I have done. I guess that is good confirmation that a career in science is right for me. I am sure I am going to graduate school.” Patrick has three publications at this point and will have two more from this SURF. Not bad for a college sophomore!

As with many, perhaps most, research groups, co-mentors—graduate students and postdoctoral scholars—regularly supervise the SURF students. Co-mentors in the Gray Group include graduate students Wendy Belliston-Bittner, Yen Nguyen, and Jeremy Weaver, and postdoc Ekaterina (Kate) Pletneva. The co-mentors and students gather in a conference room to discuss their SURF experiences.

Jeremy serves as the Gray Group co-mentor coordinator. “I told Harry one summer I wanted to work with a SURF student, and he sent everyone to me. I found places for the students I couldn’t take myself, and that is how I got the job,” he says. He has worked with Mayra Shiekh the past two summers. Asked about how he mentors her, he replies, “I make it up as I go along. If my

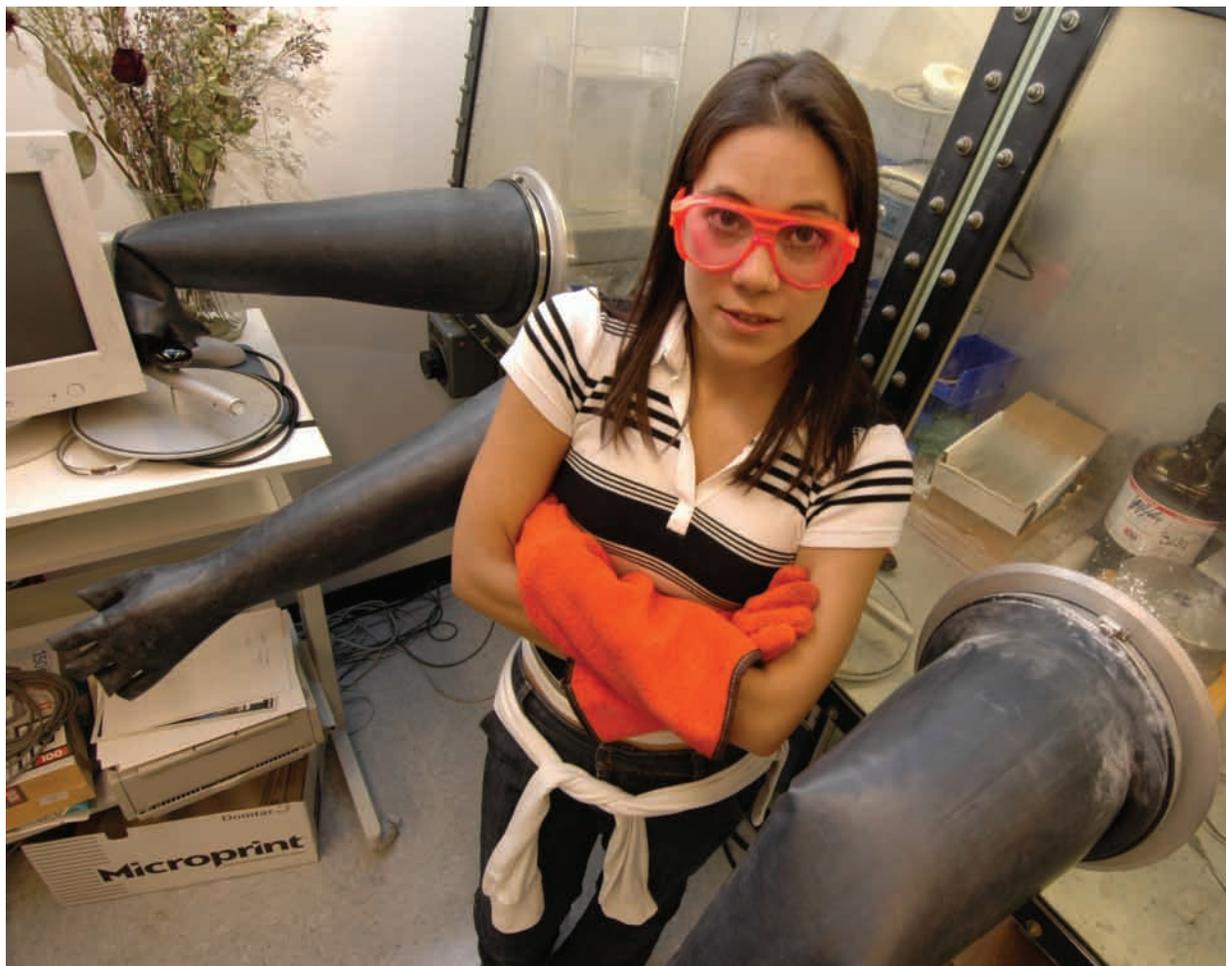
own research doesn't work out, then I decide what to do next. If Mayra's doesn't work, I have to think about how to direct someone else's project." Mayra and Jeremy joke about some of the parts of her project that have not come out as planned, and it is clear that they enjoy working together.

This is the first SURF mentoring experience for Wendy and Yen. They began by developing some small projects they thought would be interesting for an undergraduate and that would help them get some of their own work done. "We had high hopes," says Wendy. "We thought everything would go as planned."

June Wicks, a Caltech freshman and chemistry major, has been working with Wendy all summer on her project to make a molecular wire to study enzymes. "When I started, I thought I would be finished with the wire in three weeks. I was pretty optimistic. It is not finished yet!" she says.

George Matousek, a JPLUS student in his junior year at Cal Poly Pomona majoring in chemistry, agrees, "We are working on the same project—different wires but the same idea. I am still working on my wire, too. I came in with visions of working with the enzyme but it didn't work out that way." He continues, "The opportunity to be at Caltech working in a lab with these people has been fantastic."

Wendy and Yen agree that mentoring is more difficult than they thought it would be. "I felt like I had to have answers for everything, and I don't," says Yen. "I realized



June Wicks

all the things I take for granted, things I learned many years ago and now do automatically. SURF made me think of that.” Wendy adds that it was tough to remember what it was like not to know something. “I taught Mallori (Mallori Watson, a MURF student from the University of Southern Mississippi) how to use a pipette. It is something that people struggle with at the beginning. I had forgotten that. It was a good teaching experience for me,” she observes.

The students discuss the advantages of doing undergraduate research. Binghai Ling, a junior majoring in chemistry, says, “When your research doesn’t work out you redo it and redo it. That is part of research, and through SURF you get to find out whether you can deal with it. You get to spend one summer of your life finding out if this is something you like or hate rather than discovering it after years in grad school. It is better to know in one summer instead of several years!”

Mayra Sheikh, a chemistry major and a sophomore, adds, “I like doing research much better than taking classes. Lab classes have predictable outcomes. If you mess it up, there you go. In real life if you mess up once, you do it over and over until you get it right or have exhausted all possibilities. It is nice to have that experience,” she says.

Mallori Watson, a sophomore majoring in biological sciences, observes that it enhances her education. “Application is the greatest teacher,” she says. “It is so much

different from the classroom where there is a right answer and a wrong answer. Here you have to try to put it together in your own mind.” George adds that every time he has a question, Yen responds, “What do you think?” “It made the whole thing come into perspective for me,” he says. And June concludes that it opens a window to different things. “If you are not sure you like a subject, you should try it out to see what it is like.”

Binghai and Mayra comment on the SURF reporting requirements. “I like having the progress reports due as the summer goes along because when you get to the final report it is already half written,” says Mayra. “I also like the oral presentation. If you can’t teach it, you don’t know it. If you can do a presentation and answer questions, you have to know your material pretty well, and the talk forces you to know it.” Binghai adds, “If you can’t present what you have done it is as though you have not done it at all. No one else would know about it. For me, it has also been important for scholarship applications.”

Wendy summarizes, “From my observation this summer, there is a barrier to get over to realize that there isn’t an answer to

many things. Research just doesn’t work 90% of the time. Most theses are built around the 10% that worked and by putting in long hours and thinking a lot and trying different things. It is a big eye opener. It is a whole different ball game from taking an undergraduate chemistry course.” June adds, “If things don’t work [in class], you just get a point taken off, and you move on.”

Professor Gray is an enthusiastic proponent of the SURF program. “Thank goodness for SURF!” he says. “It has become part of the system at Caltech. I think all Caltech students ought to have at least one SURF experience.” Students don’t learn to love science from taking courses; they discover what they want to do by being in the lab, he thinks. “Chemistry is very exciting because there is so much going on. It interacts with biology and physics and geology and engineering. There is great stuff out there at the frontier, but there is no way you can figure that out by taking courses. SURF gets students into research labs and talking with people about what is going on. That is the most important thing. Students find out what they are good at and what they like best.”



Watson

Matousek

Sheikh

Halpern-Manners

Wicks

SURF PROFILE

PROFILE OF 2004 SURF CLASS

<i>Division</i>	<i>Total # of Students</i>	<i>CIT Students</i>	<i>Non-CIT Students</i>	<i>Mentors</i>
Biology	61	43	18	22
Chemistry and Chemical Engineering	66	42	24	28
Engineering and Applied Science	93	57	36	44
Geological and Planetary Sciences	18	12	6	15
Humanities and Social Sciences	21	15	6	13
Physics, Math, and Astronomy	61	49	12	32
JPL	68	26	42	37
Off Campus	11	11	0	11
International	9	9	0	8
TOTAL	408	264	144	210

<i>Class Level</i>	<i>Percent</i>
Pre-Freshman	1%
Freshman	18%
Sophomore	41%
Junior	35%
Senior	5%

Women	37%
Minorities	12%
Average GPA	3.48*

* Caltech students only, excluding pre-freshmen and freshmen

Statistics from the 2004 Graduating Class

Total number graduating: 208

Number of SURFers: 123 (59%)

Total number of graduates receiving honors: 107 (51% of the graduating class)

Number of SURFers receiving honors: 79 (74% of the students receiving honors)

Total number of prizes awarded: 188

Number of prizes received by SURF students: 149 (79%)

FUNDING SURF

EACH SURF STUDENT receives a stipend of \$5,000 for the ten-week summer period, a total budget of \$2 million. Most of the funds are raised annually from a variety of sources including gifts from individuals; foundations and corporations; faculty grants and other Institute sources; and NASA funds (for students working with mentors at JPL).

The Student-Faculty Programs Office, in partnership with the Development Office, raises funds to support Caltech SURF students collaborating with faculty on campus or at other universities. Typically mentors pay half the stipend, and funds raised from private external sources—individuals, corporations and foundations, and the endowment—are used as matching funds.

SURF depends upon the generosity of its many friends for annual gifts or for contributions to the SURF endowment to build a robust financial base to ensure that Caltech students continue to have the opportunity to engage in research with faculty. We thank the many donors who have supported SURF 2004!

The Campaign for SURF

The administration designated SURF as one of the priorities in the current capital campaign with a

goal of increasing the SURF endowment by \$10 million. This significant addition to the endowment will ensure the future of the program and will provide Caltech students with the unparalleled opportunities to engage in research at the frontiers of knowledge under the coaching of experienced mentors.

We are delighted to announce that Mrs. Margaret Leighton has established the Thomas Lauritsen SURF Endowment to support a student in the JPLUS (JPL Undergraduate Scholars) program or a woman SURF student collaborating with a faculty member in the Division of Physics, Mathematics, and Astronomy. We thank Mrs. Leighton for her vision and support of the SURF program and for helping to ensure the future of the program.

We thank Mr. and Mrs. Kirk Dawson for including a generous gift—the Kirk and Marjory Dawson Family SURF Endowment—in their estate plan. This generous pledge helps us meet the campaign challenge and is an outstanding investment in the Institute and its students.

Individuals or groups may establish an endowment for \$125,000 to support one student annually in perpetuity, and it may be named as the donor designates.

There are several ways to establish endowments—they may be paid in full at creation, given in installments over a period of three to five years, or specified in the donor's estate plan.

Endowment donors receive special benefits. Each year a student will be selected to bear the endowment name, and the contributor will receive a letter introducing the student and describing the project. If they choose, donors may have the opportunity to meet the students supported by their gifts, and they often receive letters of appreciation from "their" students. Donors are invited to attend SURF Seminar Day to hear the student's final oral presentation. The Student-Faculty Programs Office notifies endowment contributors when students they have supported win special recognition or publish papers. Endowment contributors can be proud of the investment they have made in the future of Caltech's bright and talented students, and they gain the personal satisfaction from playing an important part in the formation of young people, many of whom will make significant contributions in the nation and the world.

Annual Gifts

We deeply appreciate the gifts from the friends of SURF who have made contributions in all amounts to support our students in the undergraduate research enterprise. We depend upon these donations to help us build a robust financial foundation for SURF each year. Each gift is important!

We especially thank the SURF parents and alumni contributors to the program. Their gifts are a strong testimony to the value they place on the SURF experience in the undergraduate curriculum. Through their donations Caltech alumni recognize the remarkable advantages students receive from engaging in research. The gifts from Associates, good friends of the Institute as well as of SURF, keep SURF vital and ensure that Caltech remains a world leader in education.

Gifts may now be given to SURF online through the secure Alumni Fund website.

Log onto <http://www.surf.caltech.edu> and click on Making a Donation for the link. You do not have to be a Caltech alumnus to use this site! You may also mail contributions to the SURF Office, California Institute of Technology, 139-74, Pasadena, CA 91125.

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Kirk and Marjory Dawson Family SURF Endowment
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HONOR ROLL of SURF DONORS

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A portion of the following endowment, established for the Department of Environmental Science and Engineering, is used to support SURF stipends.

James J. Morgan SURF Fellowship
 Mr. and Mrs. Gordon P. Treweek*

* *These individuals contributed the amount of one or more SURF stipends.*

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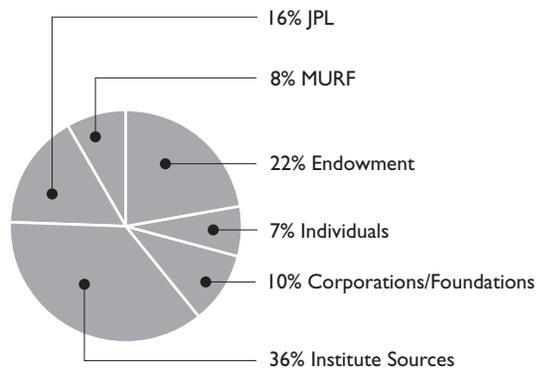
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SURF depends upon the assistance of many individuals to review students' proposals and submissions for the Marcella and Joel Bonsall Prize for technical writing, serve as session chairs on SURF Seminar Day and judge presentations for the Doris S. Perpall prize for excellent oral communication. We thank the following people for their help with SURF 2004:

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HIGHLIGHTS OF SURF 2004

The William Whitney Workshops

We are delighted to announce that the Monday Evening Professional Development Workshops have been renamed the William Whitney Workshops in recognition of Bill Whitney's initiation and implementation of them fourteen years ago. The purpose of the workshops is to help students make short-term educational and career decisions in the context of longer-term life and career goals. Bill has given much time and has worked tirelessly since the beginning to coordinate these workshops. Each week this summer close to 80 students attended these workshops, and they regularly expressed their appreciation for the sessions.

The topics and presenters for this year's Whitney Workshops included:

INVENTING YOUR FUTURE: WHAT ARE YOUR OPTIONS?

Dr. William M. Whitney (BS '51),
Deputy Manager, Education Office, JPL
Dr. Jerry Houser, *Director, Career
Development Center*

COMMUNICATION IN CAREERS

Ms. Carolyn Ash, *Director,
Student-Faculty Programs*
Dr. Steven Youra, *Director,
Hixon Writing Center*
Dr. William M. Whitney (BS '51),
Deputy Manager, Education Office, JPL

INTELLECTUAL PROPERTY

Dr. Rich Wolfe (PhD '94), *Director,
Office of Technology Transfer*

SCIENTISTS AS SPEAKERS

Dr. David L. Goodstein, *Vice Provost,
Professor of Physics and Applied Physics;
Dr. Frank J. Gilloon Distinguished
Teaching and Service Professor*

THE ART OF GRIP & GRIN: AVOID EMBARRASSMENT, BUILD RELATIONSHIPS, AND GET AHEAD WITH GOOD MANNERS

Ms. Amy Malak, *Associate Director,
Career Development Center*

GRADUATE SCHOOL: THE NUTS AND BOLTS OF THE APPLICATION PROCESS

Ms. Joni Watanabe-Tsuji, *Career Counselor,
Career Development Center*

Caltech Wednesday Seminars

This year, nine seminars were given on Wednesdays at noon by members of the Caltech faculty, covering areas of their research. The speakers and topics were:

MARIO BLANCO

Director, Molecular Process Simulation
In Search of Oil and Better Fuel Cells with
Quantum Mechanics

KENNETH G. LIBBRECHT (SURF '79)

Professor of Physics
The Physics of Snowflakes: A Close Look
at the Genesis of Pattern and Form

JESSE L. BEAUCHAMP

Mary and Charles Ferkel Professor of Chemistry
Post-Huygens Exploration of Titan: The
Search for Life on Other Worlds

JANET G. HERING

*Professor of Environmental Science and
Engineering*
Clean Water: The Oil of the 21st Century

MICHAEL E. BROWN

Associate Professor of Planetary Astronomy
Beyond Pluto: Sedna and the Edge of the
Solar System

JACQUELINE K. BARTON

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Professor and Professor of Chemistry*
DNA: A Different Perspective

MARY B. KENNEDY

Allen and Lenabelle Davis Professor of Biology
Decoding Synaptic Signaling

NATHAN S. LEWIS

*George L. Argyros Professor and Professor of
Chemistry*
Scientific Challenges in the Development
of Sustainable Energy

MARIANNE BRONNER-FRASER

Albert Billings Ruddock Professor of Biology
Neural Crest Cells: A Cell Type With Both
Face and Nerve

Each Monday and Friday, members of the JPL staff presented talks to students in SURF and other programs coordinated by the Student-Faculty Programs Office. Speakers and topics this year were:

JPL Monday Seminars

RANDII R. WESSEN

Navigator Program Engineer
The Future of U.S. Robotic Planetary
Exploration

BENJAMIN D. SMITH

Manager, Autonomous Systems Program
The Role of Autonomy in Space
Exploration

CHRISTINE CHEN

*National Research Council Resident
Research Associate*
Spitzer Space Telescope Observations of
Circumstellar Disks

POLLY ESTABROOK

*Deputy Manager, Communication Systems
and Research*
Mars Exploration Rovers:
Telecommunication Subsystem Design
and Performance Highlights

KEN BROWN

*Cognizant Engineer for Cryogenic Nulling
Interferometer Activities*
Terrestrial Planet Finder: Overview of the
Nulling Interferometer

ANDREW GRAY

Group Supervisor
Preparation for Human Exploration
of Mars

THOMAS GEORGE

Supervisor, MEMS Technology Group
MEMS and Nanotechnology for Space
Exploration

ALBERTO BEHAR

Robotics Vehicle Group

Above, Within, and Below the Ice: Polar Technology Concepts JPL and NASA Are Developing for Earth and Space

JPL Friday Seminars

JOY A. CRISP

Mars Exploration Rover Project Scientist

Mars Exploration Rover Science Results

KELLY L. PERRY

Cassini Orbit Insertion Science Planner

Cassini Saturn Orbit Insertion Science

RALPH KAHN

Lead Scientist, Earth and Planetary

Atmospheres, and MISR Aerosol Scientist,

Earth and Space Sciences Division

Measuring Aerosol Pollution From Space

MITCHELL TROY

Adaptive Optics Group Lead, Observational

Systems Division

Astronomical Adaptive Optics: Removing the Twinkle From Stars

MICHELLE THALLER

Manager, Spitzer Space Telescope Education

and Public Outreach

In the Heat of the Night

MARTIN LO

Navigation and Mission Design, Systems

Division

Planetary Flybys via the Interplanetary

Superhighway

GREGORY A. CARR

Power System Engineer, Project Element

Manager, JIMO

Jupiter Icy Moon Orbiter Power System

ANDREA DONNELLAN

Deputy Manager, Earth and Space Sciences

Division

Using Space Technology to Understand Earthquakes

ADRIAN PONCE

In situ Technology and Experiments,

Observational Systems Division

Bacterial Spores: From Detecting Anthrax Attacks to Searching for Life on Mars

RICHARD TERRILE

Mars Scout Program Scientist

Rise of the Machines: Exploring Space With Intelligent Robots

Special Events

Again this year, Dr. and Mrs.

George Boone sponsored an out-

standing tour of The Huntington

Library, Art Collections, and

Botanical Gardens that included

the new Helen and Peter Bing

Children's Garden, and the

Sugaring Off exhibit at the Boone

Gallery. The Boones hosted a

reception for students in their

sculpture garden following the tour.

The Life-Cycle Tour of JPL gave

participants a glimpse of the phases

of development of missions such as

the Mars Exploration Rover and the

Cassini Saturn Orbiter, beginning

with conceptual design, continuing

through technology development,

component fabrication, component

and system assembly, and testing,

and concluding with mission opera-

tions. We thank Bill Whitney and

David Seidel for organizing and

conducting the tour.

Awards and Prizes

Robert C. Perpall (BS '52, MS '56)

endowed a prize in memory of his

late wife, Doris S. Perpall, to

encourage students to prepare

excellent SURF presentations.

Winners of the 2003 Perpall prize

were:

Joseph E. Gonzalez

1st Prize

Salomon J. Trujillo

2nd Prize

Miling Yan

3rd Prize

The late Marcella Bonsall, a long-

time member of the SURF Board,

endowed the Marcella and Joel

Bonsall Prize for Technical Writing

as an incentive for students to

develop strong technical skills.

Winners of the 2003 Bonsall Prize

were:

Maryam Ali

Abigail T. Crites

Aidan Crook

Elena A. Fabrikant

Tomonari S. Miyashita

Belle E. Philibosian

John P. Sadowski

Conferences

SURF Seminar Day was held October

16, 2004, on the Caltech campus.

The SURF program requires stu-

dents to give either an oral or

poster presentation to an audience

of peers, faculty, mentors, alumni,

donors, families, and prospective

students. This presentation is the

capstone of the SURF experience.

National Conference on Undergraduate

Research (NCUR) drew over 2,000

undergraduates, faculty, and admin-

istrators to Indiana University-

Purdue University Indianapolis.

Students presented their research,

scholarly, and creative activities in

oral and poster sessions. Caltech

presenters for 2004 were:

Lea Hildebrandt

Matthew Johnston

Po-Ru Loh

Jennifer Treweek

Miling Yan

Southern California Conference on

Undergraduate Research (SCCUR)

was held at the University of

California at Irvine in November

2003. It brought close to 1000

students from regional colleges

and universities to present their

research in oral and poster sessions.

SCCUR is multi-disciplinary includ-

ing the sciences, the humanities,

social sciences, art, and perform-

ance. SCCUR was started at Caltech

in 1993.

SURF student presenters at

SCCUR 2003 were:

Wei Lien Dang

Charlotte Guo

Tracy Janov

Mazhareddin Taghivand

Vivian U

SURFSAC Suppers

Again this year, the SURF Student Advisory Council coordinated weekly suppers for Caltech faculty and small groups of students at local restaurants to encourage informal conversation between students and mentors. We thank Catherine Jurca, Master of Student Houses, for generously subsidizing the cost of these popular suppers.

SURFSAC Goldstone Trip

Shannon Lewis, SURFSAC member, arranged a special tour of the Goldstone Deep Space Communications Complex near Barstow, California. The tour included visiting many of the deep space antennae, including the extraordinary 70-meter dish, and the Goldstone museum.

Allied Programs

The Student-Faculty Programs Office administers an array of undergraduate research programs including:

- > Laser Interferometer Gravitational-Wave Observatory (LIGO) program in the physics department
- > NASA Undergraduate Student Research Program (USRP) at JPL
- > NASA Space Grant at JPL
- > NASA Planetary Geology and Geophysics Undergraduate Research Program (PGGURP) at JPL

When students are admitted to these programs, they become part of the SFP contingent. They may attend all activities planned by the Student-Faculty Programs Office including the Whitney Workshops, weekly seminars, and social and cultural events. The non-Caltech students may live in student housing.

All Student-Faculty Programs participants have similar requirements. Students must write either a research proposal or a project plan prior to the start of the program. They must conduct their projects for ten weeks, give an oral presentation, and write a technical paper at the conclusion. They receive stipends of \$5000. The total number of students in all SFP programs for 2004 is 516.

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SUMMER Undergraduate **RESEARCH** Fellowships



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