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United States House of Representatives

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Chairman Inglis and distinguished members of the Subcommittee, I appreciate the opportunity to participate today in hearings on "Undergraduate Science, Mathematics, and Engineering Education: What's Working."

There is a story many of us like to tell about what has made America's economy run like clockwork that goes like this:

(1) Investment in instruction
(2) Invigorates innovation and
(3) Increases incomes.

This three-step process for producing prosperity and progress is somewhat oversimplified, as I will point out. But that has hardly mattered much in the past because the theory was not testable anyway. We could not, after all, run history over again to experiment with whether investing in Science, Technology, Engineering, and Mathematics (STEM) education as we did, say, after Sputnik, really was an important cause of our subsequent economic prosperity and growth.

The good news is that we now have better evidence that some form of this STEM-winder story was right all along. The bad news, according to many Americans, is that this evidence is being generated in countries like China and India rather than in the U.S. But is this such bad news? A threat to our nation? A perfect storm that will wash away all we treasure?

Opportunity or Threat?

I want to begin by arguing that, although global trends in STEM education and employment do demand our attention, we should welcome them for at least three reasons besides the fact that us storytellers are being proven correct:

First, these global trends are good for the world. We are witnessing how STEM education can lift diverse, poor, and even hopeless people from socio-economic status lower than most Americans can imagine into the stable middle or even entrepreneurial classes of their countries. Science need not discriminate on the basis of race, religion, or gender; its efficacy is a heritage potentially available to all. And in a world that feels more and more like it is about to fall apart, we can still communicate and agree about scientific findings more easily than about matters that divide civilizations.

Second, these trends are good for science. There is growing excitement and enthusiasm all over the world for STEM and STEM education. And so there is so much we can learn from one another, especially if the U.S. remains a hub for the scientific exchange of both people and ideas. Enthusiasm and excitement about STEM still exists among many young Americans, too, not to mention a great deal of idealism in the undergraduates I meet about dedicating their talents to serving others and solving problems by teaching, innovating, and leading: they volunteer to Teach for America; they want to help address world-wide challenges like AIDS or global warming or sustainable energy or cybersecurity; and some just want to make an amazing discovery or start the next big high-tech company along the way, too.

A third reason why the trends abroad are good is that they provide a wake-up call. We must re-examine our STEM policies and practices in ways that mattered less when the U.S. enjoyed such undisputed dominance in science and technology. For decades, the oversimplified STEM-Winder story we started with was good enough. Now it is time to examine, critique, and refine how we imagine and design policy based on each of the three steps in our recipe for economic bliss.

The Chinese Army

As an organizational leader these days, one of my favorite questions is, “What problem are we trying to solve?” Our challenge today is not simply to devote more dollars to STEM, or even to create more STEM majors. Those may be means to an end, at least if we go about such tasks wisely. But the real goal is to reap the prosperity and progress promised by our original story. Most recent attention has focused on how many STEM specialists different countries are educating. What conclusion should we draw from reports that, while the U.S. trained 70,000 new engineers in 2005, India produced 350,000 and China 600,000? Or was it only 400,000 in China (they counted people without B.S. degrees) and 100,000 in the U.S. (including computer scientists as in the Chinese data)?

As a mathematician, I am very suspicious about numbers (though I am sometimes impressed by growth rates). The Chinese Army is also very big, after all. But quality counts as well as quantity. What gives me faith in the U.S. military has less to do with efforts to recruit more individuals (especially since we cannot keep up anyway) than with the teamwork, communications, leadership, creativity, and innovation embodied in its institutions. Similarly, I want to emphasize and illustrate how STEM policy recommendations should not only support incentives for individuals, but also support the kinds of infrastructure and institutions those individuals need to get the job done well. This point of view helps, at each step, with distinguishing among: (a) good policies aimed at individuals; (b) better policies that address the collective nature of STEM work; and (c) best examples to inspire us.

Step 1: Will investing in education produce more STEM workers?

(1a) There are currently some good policy recommendations before Congress dealing with individual incentives. Kavita Shukla in her bachelor's degree thesis at Harvard, recently asked fellow students about the $20,000 annual scholarships for STEM majors called for by the NRC report Rising Above the Gathering Storm (RAGS). While 50% professed no interest whatsoever in science or engineering, 14% said they would switch to a STEM field if such support were available. At present, only 18% of Harvard undergraduates are STEM concentrators, so this would be a huge increase.

Will there be enough students arriving at college with the prerequisites to make such a switch into STEM fields? RAGS sets ambitious goals for expanding Advanced Placement classes in high school. One basis for my confidence that we can meet these goals has been the success of the ThinkFive Services for supporting AP teachers and students online, whose development I helped advise in partnership with AgileMind, Inc. and the Dana Center at the University of Texas at Austin.

Will there be enough qualified teachers? Again, I take heart from the success of examples like the "Masters in Mathematics for Teaching" degree program founded as a partnership between the Harvard Mathematics Department and the Division of Continuing Education.

Will undergraduates continue on in STEM? Tables in Appendix 2 show that applications for NSF graduate fellowships improve both quantitatively and qualitatively in response to the kinds of spending enhancements advocated by RAGS. This data was compiled by Richard Freeman and Tanwin Chang for the Scientific and Engineering Workforce Project at the National Bureau of Economic Research.

(1b) While we can help produce more STEM degree holders in these ways, will they then go on to become working scientists and engineers? The opportunity costs to a U.S. undergraduate incurred by going into the life sciences, say, as opposed to business, law, or medicine are substantial—approximately $1 million in present value according to calculations by Richard Freeman. So policy must also address retention through means that are not just financial.

Besides dollars, what makes people persist in their fields is a shared sense of collective purpose and mutual support. This sense of community is what works in the military, after all. Policies will therefore be even more effective to the extent that they build infrastructure and institutions that reduce uncertainty, indignities, and delays for groups of young STEM workers.

(1c) The best policy levers for promoting the healthy growth of STEM communities are, for now, at the National Science Foundation (NSF). It is no secret that the Education and Human Resources (EHR) Directorate at NSF is being decimated. Significant funds have been taken out of the hands of scientists, engineers, and mathematicians there, and transferred to the Department of Education. This may or may not make sense for K-12. But the staff and clientele of the Division of Undergraduate Education (DUE) at EHR used to represent a strong community of expertise dedicated to improving STEM education at the college level. While funding can and should be restored and predictably grown at least in proportion to total NSF budget growth, the community associated with DUE is in danger of scattering irretrievably.

Step 2: Will more STEM workers produce more innovation and invention?

(2a) The RAGS report is one of dozens of similar accounts that implicitly link the number of STEM workers present with the rate of technological innovation and invention. Obsession with counting bodies seems rooted in romantic idealism about scientific discovery: inspiration, like lightning, unpredictably strikes those with good STEM educations, so the more well-educated lightning rods in your country, the higher the likelihood of a hit? Again, we are not so special that we can ignore lessons from other countries. During the Cold War, for example, the Soviet Union did not innovate or invent in proportion to its highly talented, vast, and technically well-trained workforce--mainly because the economic infrastructure functioned so poorly under communist central planning.

Of course, the RAGS report does present good suggestions for providing individual incentives and rewards to STEM workers who innovate or invent, including 200 new grants of $500,000 over five years for young researchers as well as a new Presidential Innovation Award. These would be welcome additions to the already large number of “winner-take-all” tournaments in STEM. But Richard Freeman has pointed out that, although setting up competitions this way may motivate people who believe themselves likely to win, many others may also be discouraged from trying their best. Compared to schemes that acknowledge and reward cooperation, the net result could actually be less effort and fewer discoveries in total.

It is not just individual winners, but whole communities that are important enablers of STEM progress. The number of research papers or patent applications with multiple authors has been exploding relative to the number from lone geniuses. It takes teamwork, communication, as well as interactions within and between fields to make discoveries. Rather than flashing from the sky, think of scientific energy as coursing around networks. Scientists are at the nodes of these networks, and I am all in favor of increasing their numbers, but it is the strength, density, reach, and interfaces of their networks (STEM cells?) that promote the innovation and invention we seek.

(2b) In the STEM wars, then, as in military or political campaigns, the one with the biggest staff does not necessarily win. We have to make sure our forces are well deployed, equipped, connected, and coordinated if we expect results against overwhelming odds. So better policy menus will not just address individuals, but also support institutions and infrastructure, associations and assemblies, international and interdisciplinary interactions, etc. Besides the hardware in laboratories, the software in machines, and the wetware in brains, we need this kind of fragile STEM-ware, too, to give shape to scientific efforts that might otherwise be fluid, fleeting, and dispersed.

(2c) The best example of a group that has vigorously promoted innovation and invention by STEM faculty and students has been Project Kaleidoscope (PKAL). Founded in 1989 as an ad hoc organization, PKAL is dedicated to improving the environment for undergraduate STEM education--including everything from the design of science buildings to the career development of young academics. Most recently, PKAL has also worked on establishing international exchanges of undergraduate STEM activists. The spectacular success of this kind of association needs to be institutionalized and expanded, perhaps in the form of a national center for undergraduate STEM education.

Step 3: Will innovation and invention produce more progress and prosperity?

(3a) The RAGS report also presents good suggestions for providing incentives to individual corporations and commercial endeavors in the U.S. New R&D tax breaks and intellectual property protections would certainly be welcome by those organizations. This is the RAGS to riches section of the report.

(3b) But if globalization teaches us anything, it is that new ideas do not stay put. So even if, in the romantically idealistic account, inspirational lightning strikes a scientist in one country, there is no real way of stopping that energy from being transmitted, sooner or later, to other specialists and entrepreneurs throughout the world. Who eventually benefits? We all might, when discoveries lead to better, cheaper, or more healthy products. The real question, however, concerns whether new industries and their profits are retainable within one country or another. We often talk as if comparative advantage in high technology production necessarily accrues to nations with a large and inexpensive supply of interchangeable STEM workers. Perhaps it is the networks that matter more than the individuals for this purpose, too. Think of the robust economic success embodied by communities that are close-knit, well-connected, and have well-established rules for trust and competition like Silicon Valley, the consumer electronics business in Finland, the diamond district in New York, or the shipping trade in Hong Kong. Such examples are the result of high investments not just in human capital, but in social capital—that is, in the ability to form and sustain mutually beneficially relationships.

(3c) The best example of how to form mutually beneficial relationships between undergraduate STEM students and STEM employers is the Clinic Program at Harvey Mudd College (HMC). For over 42 years, companies, national laboratories, and others with real technical problems they need solved have been bringing them to the Clinic Program for small groups of undergraduates to solve. Last year alone, the sponsors, who retain the intellectual property rights to the work, put students names on 13 patent disclosures. Whole divisions and product lines of corporations have been based on HMC projects. The students, in turn, learn about communication skills, teamwork, leadership, and innovation in addition to technical matters. A list of sample clinic projects appears in Appendix 4.

Harvey Mudd College also conducts undergraduate research under other programs on topics ranging from the use chitosan—a remarkable healing agent secreted by shrimp shells—in hemorrhage control bandages to the mechanisms specific enzymes use to repair and remove damaged DNA; and from the design and testing of new GPS protocols to the invention of portable systems that give first responders a few minutes warning before a burning building collapses.

Projects like these are not part of undergraduate education in other countries. Precisely because China and India have such enormous populations, their institutions of higher education operate at scales that do not facilitate the selection or education of students for creativity. The four-year liberal arts college is a uniquely American invention whose students contribute disproportionately to the STEM workforce. The economics of higher education, particularly in STEM fields, is particularly challenging at small schools like these. Like PKAL and DUE, the continuing ability of these institutions to continue their good work is not assured without some wise and timely policy interventions. The short answer about what works is community. That is why recommendations and reforms should support not only individual incentives, but also infrastructure and institutions.

With less than 6% of the world's population, the United States cannot expect to dominate science and technology in the future as it did during the second half of the last century when we enjoyed a massively disproportionate share of the world's STEM resources. We must invest more the resources we do have, encourage those resources to produce economically useful innovations, and organize the STEM enterprise by working with diverse groups to make sure that innovations developed here or overseas produce prosperity and progress for all.

Many believe that U.S. investments in STEM education following Sputnik paid off handsomely in later technological and economic advances. In 2005, word came that the European Union is sponsoring a satellite designed and built entirely by students. We must rededicate ourselves to what is working in undergraduate science, mathematics, and engineering education.

Daniel L. Goroff

Daniel Goroff is Vice President for Academic Affairs and Dean of the Faculty at Harvey Mudd College. He has held this post since July of 2005, when he also became a member of both the Mathematics and the Economics Departments.

Goroff earned his B.A.-M.A. degree in mathematics *summa cum laude* at Harvard as a Borden Scholar, an M.Phil. in economics at Cambridge University as a Churchill Scholar, and a Ph.D. in mathematics at Princeton University as a Danforth Fellow.

Goroff's first faculty appointment was at Harvard University in 1983. He is currently on leave from his position there as Professor of the Practice of Mathematics, having also served as Associate Director of the Derek Bok Center for Teaching and Learning, and Resident Tutor at Leverett House.

A 1988 Phi Beta Kappa Teaching Prize winner, Goroff has taught courses for the mathematics, economics, physics, history of science, and continuing education departments at Harvard. He was also the founding director of a Masters Degree Program in "Mathematics for Teaching" offered through the Harvard Extension School.

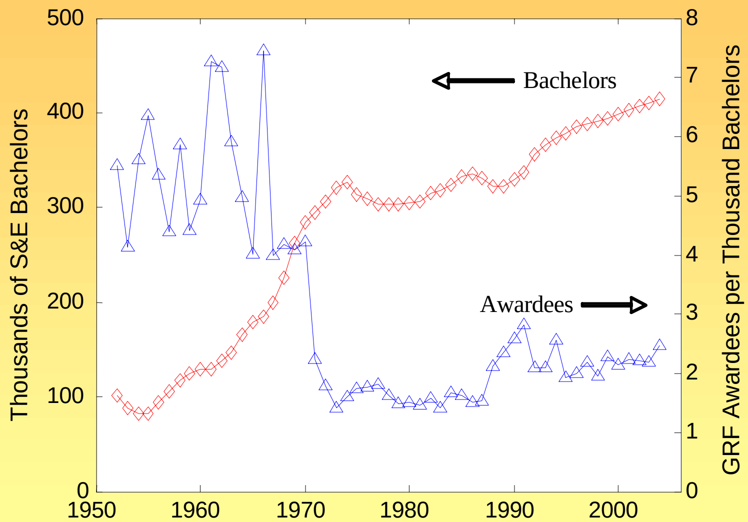
In pursuing his work on nonlinear systems, chaos, and decision theory, Daniel Goroff has held visiting positions at the Institut des Hautes Etudes Scientifiques in Paris, the Mathematical Sciences Research Institute in Berkeley, Bell Laboratories in New Jersey, and the Dibner Institute at MIT.

In 1994, Goroff was elected to a three-year term on the Board of Directors of the American Association for Higher Education (AAHE). During 1996-97, he was a Division Director at the National Research Council (NRC) in Washington, and during 1997-98, Goroff worked for the President's Science Advisor at the White House Office of Science and Technology Policy (OSTP). That year he was named a "Young Leader of the Decade in Academia" by *Change: The Magazine of Higher Education.*

As Director of the Joint Policy Board for Mathematics (JPBM) from 1998 to 2001, Daniel Goroff was called to testify about educational and research priorities both by the House and again by the Senate during the 106th Congress. He currently serves as Chair of the U.S. National Commission on Mathematics Instruction at the National Research Council, and co-directs the Sloan Scientific and Engineering Workforce Project at the National Bureau of Economic Research.

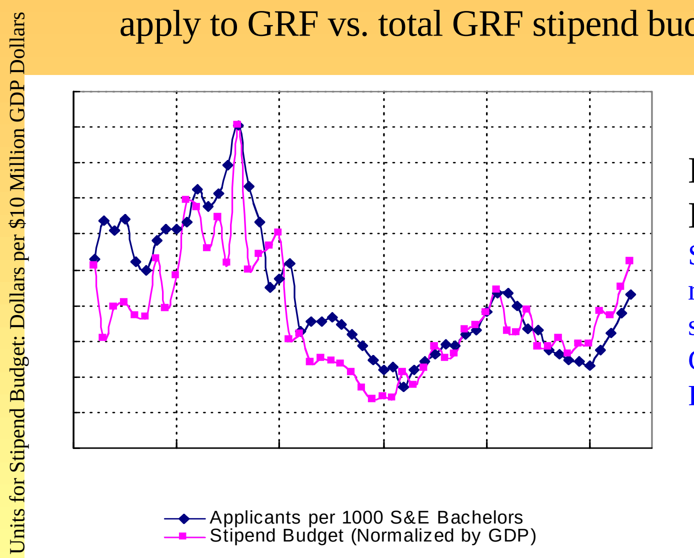
Appendix 2: NSF Graduate Research Fellowship Data
Prepared by Richard Freeman and Tanwin Chang for the Scientific and Engineering Workforce Project of the National Bureau for Economic Research.

GRF Awardees as Proportion of S&E Bachelors (1952 - 2004)



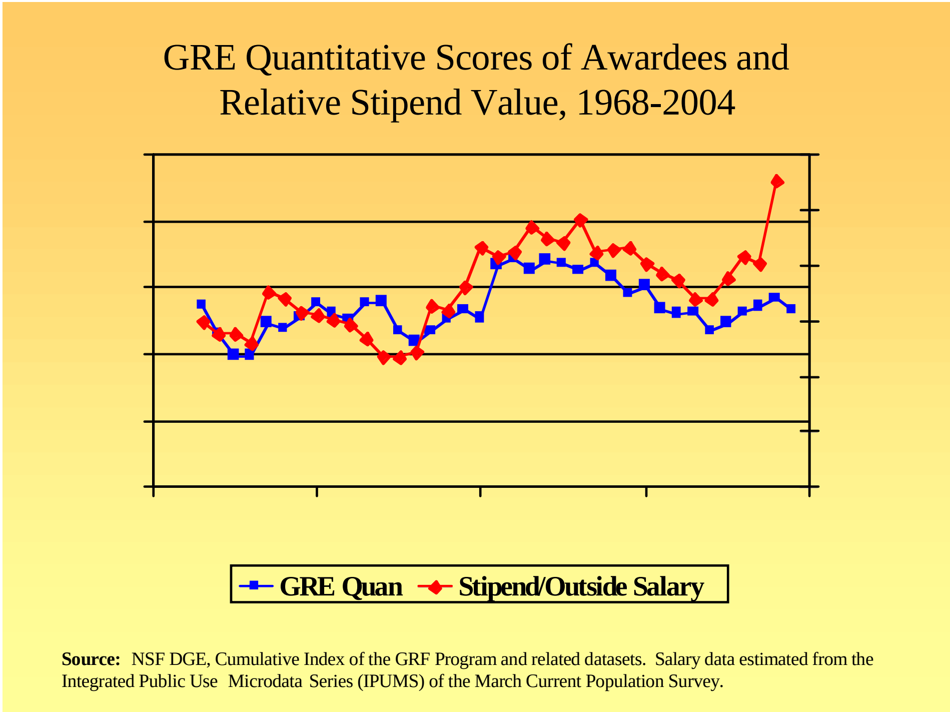
The number of awards per S&E baccalaureate has shifted downwards

Fellowships Fraction of Bachelors choosing to apply to GRF vs. total GRF stipend budget/GDP.



Bottom Line Message:
Students respond to spending on Government Fellowships

Source: NSF DGE, Cumulative Index of the GRF Program and related datasets. Data on the Gross Domestic Product (GDP) from the Bureau of Economic Analysis, an agency of the U.S. Department of Commerce.



Appendix 3: Facts about Harvey Mudd College

A member of the Claremont University Consortium, Harvey Mudd College was founded in 1956 as “The Liberal Arts College of Science, Mathematics, and Engineering” and remains true to its mission statement:

> Harvey Mudd College seeks to educate engineers, scientists, and mathematicians well versed in all of these areas and in the humanities and social sciences so that they may assume leadership in their fields with a clear understanding of the impact of their work on society.

The students at HMC are truly among the best and the brightest in the United States. According to applicant pool data, the four institutions with the greatest number of overlap applications are MIT, U.C. Berkeley, Caltech, and Stanford. Statistics for the 2005-6 entering class include:

- Median SAT 1480
- 27% National Merit Scholarship finalists
- 91% in top 10% of their senior class
- 26% valedictorians
- 35% women
- 35% students of color.

HMC ranks 18 among liberal arts colleges in the *U.S. News & World Reports* survey, and second among undergraduate engineering programs. The *Washington Monthly* placed HMC fourth in its ranking of "what colleges are doing for the country."

In 1997, HMC became the first undergraduate institution to win the prestigious International Association of Computing Machinery Programming Contest from among over 1000 entries worldwide. In the prestigious William Lowell Putnam Mathematical Competition, HMC teams have earned top-ten spots in three of the past four years and finished twice in the top five, a record unsurpassed by any other undergraduate institution.

In 2005, the American Mathematic Society presented HMC with its first-ever "Award for an Exemplary Program or Achievement in a Mathematics Department." The citation reads:

> The American Mathematical Society (AMS) presents its first Award for an Exemplary Program or Achievement in a Mathematics Department to Harvey Mudd College in Claremont, California. The Mathematics Department at Harvey Mudd College excels in numerous dimensions. Its exciting programs have led to a doubling of the number of math majors over the last decade. Currently more than one out of every six graduating seniors at Harvey Mudd College majors in mathematics or in new joint majors of mathematics with computer science or mathematical biology. Furthermore, about 60% of these math majors continue their education at the graduate level.
>
> The Harvey Mudd College Mathematics Clinic has served as a trailblazer and a model for other programs for more than thirty years. This innovative program connects teams of math majors with real-world problems, giving students a terrific research experience as well as a glimpse at possible future careers. Undergraduate research is a theme throughout the mathematics program at Harvey Mudd College, as exemplified by the over twenty papers published in the last three years by Harvey Mudd College mathematics faculty with student co-authors.

Appendix 4: The Clinic at Harvey Mudd College:

- Sponsor proposes real problem
- The responsible Clinic Director appoints a *team* of 3-5 students, a student *project manager*, and a *faculty advisor*
- The sponsor appoints a *liaison*
- The students prepare a *work statement* (subject to liaison agreement) to produce scheduled deliverables:
  - Presentations, reports, prototype, models, analyses, code…
- No guarantee of unique solution
- Fee paid by Sponsor = $41,000

Clinic Project Selection:

- Must be important to Sponsor
- Emphasizes design and experimental skills
- Allows for team interaction
- Work scope 1,200-1,500 person hours
- Fixed end date
- Concrete measurable goals

<u>Computer Science Clinic Examples</u>

The Boeing Company/ATM (2002-03)
Design and Prototype of a Low-Cost Weather Information System for General Aviation
Liaisons: James Hanson ’64, Paul Mallasch
Advisor: Geoffrey Kuenning
Students: Paul Paradise, Luke Hunter, Kyle Kuypers, Rafael Vasquez

Boeing ATM has tasked us with the design and implementation of a proof-of-concept design for delivering weather data to aircraft pilots in-flight. Using a Pocket PC PDA as a hardware architecture and a custom client and server, we are able to deliver METAR (Meteorological Reports) and NEXRAD (NEXt-generation RADar) to pilots. Our current implementation uses 802.11b wireless technology for the communication, but is ideally suited for satellite-based broadcast as a final product.

Medtronic MiniMed (2003-04)
Diabetes Data Management Software API Design and Implementation
Liaison: Pam Roller
Advisor: Belinda Thom
Students: Jessica Fisher, Mark Fredrickson, Aja Hammerly, Jon Huang

With approximately 17 million people in the US with diabetes, Medtronic MiniMed has produced several distinct lines of diabetes devices to aid in the treatment of the disease. These devices, however, do not utilize a standard communication format. The Clinic team is designing and implementing an extensible interface that will unify communication with Medtronic MiniMed's current and future insulin pumps, glucose sensors, and related diabetes technology.

Engineering Clinic Examples

The Aerospace Corporation (2003-04)
Development of Picosat Add-nn Boards
Liaisons: Samuel Osofsky ’85, Nelson Ho
Advisor: John Molinder
Students: Andrew Cole (Team Leader), Nathan Mitchell, Brian Putnam, Daniel Rinzler, Gabriel Takacs, Philip Vegdahl

Picosats are very small satellites (typically a 4” cube) launched in conjunction with a larger satellite. Aerospace designed the original Picosats, with the first placed in orbit in 2000. The technology has the potential to be used for a variety of tasks, including imaging of the launch vehicle to evaluate damage. A Harvey Mudd College Engineering Clinic team developed digital camera and GPS add-on boards for the Picosat platform. A single board was designed that is able to support either a camera or a GPS daughterboard. The engineers at Aerospace were surprised and pleased that the team was able to accomplish the project goals using primarily commercial off-the-shelf technologies, thus increasing the system’s reliability. The board is provisionally scheduled to fly on an upcoming Space Shuttle mission.

Center for Integration of Medicine and Innovative Technology (2004-05)
Design of a Prototype Cooling System to Prolong and Preserve Limb Viability
Liaisons: Alex Pranger ‘92/’93
Advisor: Donald Remer
Students: Nicolas von Gersdorff (Team Leader), Jay Chow, Michael Le, Robert Panish, Ajay Shah

While combat armor advancements have increased soldiers’ survival rates, modern weaponry ravages warfighters’ extremities, causing massive trauma and tissue loss; 2/3 of the more than 10,000 combat injuries in Iraq and Afghanistan afflicted patients’ limbs. Inducing local hypothermia (i.e., significant cooling of the affected limb) would prolong limb viability, lengthening the window for soldiers to obtain restorative and regenerative care and thereby avoid amputations. The Harvey Mudd team developed a lightweight, easily deployable, evaporative cooling wrap to induce therapeutic hypothermia on the battlefield. A patent disclosure has been filed, and the next stage of development is underway by the project sponsor.

Fluidmaster, Inc. (2004-05)
Innovative Designs for Flushing Systems
Liaisons: Chris Coppock
Advisor: Lori Bassman

Students: Joe Laubach (Team Leader), Shawna Biddick, Rami Hindiyeh, Joey Kim, John Onuminya, Sarah Taliaferro

Fluidmaster Inc. is a worldwide supplier of plumbing products. The company is determined to aid in the conservation of scarce fresh water as well as to enable people worldwide to enjoy the benefits of safe and reliable sanitation. This requires a cost-effective and reliable flushing system that uses a consistent low volume of water regardless of variations in supply water pressure and toilet resistance. The HMC team designed and prototyped two designs that accomplished these goals, resulting in a reduction of 0.1 gallon per flush, a potentially very significant improvement. Two provisional patents were awarded to the team, and Fluidmaster has indicated their intention to take one of the designs to market.

UVP, Inc. (2004-05)
Uniform Illumination for Fluorescent In Vivo Imaging
Liaisons: Sean Gallagher, Darius Kelly, Colin Jemmott '04
Advisor: Qimin Yang, Deb Chakravarti (KGI)
Students: Alyssa Caridis (Team Leader), Stephanie Bohnert, Ekaterina Kniazeva, Erika Palmer, Laura Moyer, Jeremy Bolton (KGI), Linda Chen (KGI)

In order to improve the accuracy and effectiveness of live animal *in vivo* imaging, UVP tasked a team of Harvey Mudd College and Keck Graduate Institute students to design, simulate, and test innovative imaging systems to achieve unparalleled illumination uniformity. Uniform lighting is needed for quantitative analysis of images of live creatures, which are used for research into cancer and other diseases. The team developed novel methodologies for measuring light uniformity as well as several successful designs for the lighting system itself. A successful 3-D image lighting system will allow researchers to follow the pattern of tumors in the same test animal, improving the understanding of the disease and simultaneously reducing the number of animals needed for such tests. UVP filed several patent disclosures based on the team's work, and is in the process of bringing one of the designs to market.

Mathematics Clinic Examples

HP Labs (2004-05)
Analyzing and Correcting Printer Drift
Liaisons: John Meyer, Gary Dispoto
Advisor: Weiqing Gu
Students: Jeffrey Hellrung (PM), Brianne Boatman, Durban Frazer, Katie Lewis

In color printing, a lookup table (LUT) is a mapping from a computer's color space to the ink combinations required to print these colors. An LUT will drift over time due to a variety of factors including mechanical and environmental changes, resulting in an undesirable change in the printed results. Currently, constructing a new LUT is a time consuming process. This project focused on developing a quicker method to recalibrate a printer when drift occurs.

VIASAT, INC. (2001-02)
Using Elliptic Curve Cryptography for Secure Communication
Liaison: Hunter Marshall
Advisor: Weiqing Gu
Students: Simon Tse (TL), Colin Little, Cameron McLeman, Braden Pellett

The ViaSat clinic team will present methods for performing secure cryptography over an insecure network by 1) Introducing the use of algebraic objects known as elliptic curves to accomplish this task 2) Presenting Diffe-Hellman key exchange protocol using elliptic curve cryptogtaphy (ECC) 3) Discussing potential attacks on this cryptosystem and 4) Demonstrating their implementation of this algorithm allowing two>network users to agree upon a secret key over an insecure connection.

<u>Physics Clinic Examples</u>

University of California Irvine Department of Otolaryngology (2003-04)
Modification of a Laryngoscope for Optical Coherence Tomography
Liaison: Brian Wong
Adivisors: Elizabeth Orwin, Robert Wolf
Students: Nikhil Gheewala (PM), River Hutchison, Tonya Icenogle, Rachel Lovec

Currently laryngeal cancer can only be diagnosed with biopsies which are invasive, permanently damaging, and can miss cancerous tissue. Optical Coherence Tomography (OCT) is an imaging technique that non-invasively images several millimeters into tissue to seek structural abnormalities, which can indicate cancer. We will design and construct an OCT device for attachments to a laryngoscope that will image two-dimensional cross-sections in the larynx, for the purpose of diagnosing laryngeal cancer in its early stages.

Sandia National Laboratories
Optical Characterization of Coated Soot Aerosols or "Flames and Laser"
Fall 2004 Students: Mark Dansson, Rachel Kirby, Tristan Sharp, Shnnon Woods, Mike Martin. Spring 2005 Students: Patrick Hopper, Brendan Haberle, Matt Johnson, Julie Wortman, Mark Dannson, Octavi Semonin.
Advisor: Peter Saeta

The optical properties of coated soot aerosols produce the greatest uncertainty in climate change models. This project aims to measure the scattering and absorption of light by sub-micron-sized soot particles similar to those produced in diesel exhaust. Total absorption and scattering cross sections of 635 nm laser light are measured using cavity-ringdown and angle-resolved scattering techniques. Soot particles are created in situ by partially combusting ethylene and coated with a volatile organic compound.