Students:  Bright, Inventive, Fearless

¾ of 2017's AmEx team...
Students: *Bright, Inventive, Fearless*

- **Most selective Liberal Arts College based on ACT/SAT**
  - 829 students 12% admit rate
  - Competition: Stanford, MIT, Caltech
  - Valedictorian or Salutatorian: 47%
- **45% go on to attain advanced degree**
  - Ranked #2 for Ph.D. pursuit
- **Mathematical and Interdisciplinary Contests in Modeling (MCM/ICM)**
  - Most “Outstandings” in the contests' history
- **ACM International Computer Programming Competition (ACM)**
  - Most recent US, only undergraduate school to win

Harvey S. Mudd, mining engineer
Harvey Mudd College: prioritizing both Engineering and the Liberal Arts
Clinic Program ~ founded in 1963 as an Engineering Education Innovation

Over 1,500 projects completed to date…

Directors:

- Engineering: Profs. Kash Gokli & Qimin Yang
- Mathematics: Prof. Weiqing Gu
- Physics: Prof. Peter Saeta
- Global Clinic: Prof. Susan Martonosi
- Computer Science: Prof. Zach Dodds
- Director of Corp. Relations: Colleen Coxe
What is Clinic?

- **Sponsored Capstone-Project Course**
- starts in September, delivers in May
- team of 4 - 5 students & faculty advisor
- 10 hours/student/week: 1,200 - 1,500 hours total
- Fee is $50,000
- Sponsor owns all IP
Sponsor Benefits

• Project deliverables
  • All IP, patents, products
  • Mid-year and final report
  • All software, prototypes, documentation, hardware, …

• Opportunities for recruiting
• Shaping student-education & -paths
Sponsor Obligations

• Provides project idea / description
  • We invite iteration on details, if you’d like…

• Provides liaison (~1-2 hrs/week)

• Provides fee ($50k, split into 3 payments)

• Business agreement (~3 pages)

• Feedback at end of project
Clinic's timeline

- **Fall, Winter, Spring** — Contact potential sponsors. Gather and iterate on project ideas.
- **Jan. to April** — Prepare 1-2 page project statement, execute business agreement.
- **by 1 July** — PS and BA due.
- **July/August** — Post project statement for students, prepare for student teams.
- **1st Tuesday in Sept.** — Projects start.
- **1st Tuesday in May** — Projects Day.
First Step: Identify a Project

- **Sponsor provides a written project statement**
  - tuned, if desired, with Clinic Director, for scope-matching to students’ background, interests; 9-month academic span
  - *Recipe ~ well-scaffolded start / MVP; open-ended onward*

- **Sponsor appoints a liaison to**
  - Monitor team progress, ~1 hr/week
  - Provide domain expertise, and
  - Ensure the path taken is of value to sponsor

- **Sponsor and HMC sign business agreement**

- **Faculty assigned, via interest and expertise**

- **Students assigned, via preferences and abilities**
The Year’s Start: Orientation Day

• Liaisons invited to campus
• Meet with Clinic Director
  ▪ Strategies and tips
• Meet with team and faculty advisor
  ▪ Cover problem in detail
  ▪ Discuss confidentiality
• Establish communication routine
  ▪ Email/Slack/other
  ▪ Weekly teleconferences
• Jumpstart the project, face-to-face
• Recruiting / internship opportunity
Year’s End: Projects Day

• Sponsoring organizations invited to campus
• Presentations and poster sessions by all teams
• Celebration of student work and the year’s progress
Year’s End: Projects Day

MITRE team @ poster, 2017
2017 Clinic Sponsors
**Project? Recommendations:**

- Sponsor value greater than fee
- Valuable, rather than critical …
- Job jar ~ speculative opportunities
  - "If I had one more FTE"
- No typical Clinic project:
  - "R + D for our R & D"
  - "Optimizing – on a new axis…"
  - "Piloting hackathons’ 2-5%"

*Thoughts?*
2016 Clinic Sponsors
Example clinic projects...

Apatite to Zircon, 2015
Remaining slides are extra...
Android phones are insecure

We have identified and addressed two common types of security vulnerabilities related to the Intents system (Android’s application communication system).

Applications in Google’s Android operating system communicate via messages called Intents. Novice developers often write code that creates security holes by misusing the Intents system.

Applications can leak your information

Sending the wrong kind of Intent can broadcast sensitive information to other applications.

Intents can be explicit (having a specific target) or implicit (with a target determined at runtime). Intent leakage occurs when a malicious application intercepts an implicit Intent that it was not supposed to receive.

Controlling Intents projects information

Only broadcast information if the sender can’t process it.

If an application can handle an Intent it sends, we deliver the Intent only to the sender on the assumption that it is meant for internal use. Otherwise, since the Intent was obviously meant for another application, it can be broadcast safely.

Apps can get hijacked by other apps

Trying to filter Intents makes an application publicly visible.

Android allows an application to declare an Intent filter, which specifies the types of Intents it can handle. Declaring an Intent filter causes an application to become exposed to sensitivity leakage. Intent spoofing occurs when an exported application receives and handles an Intent from an unexpected source. This behavior could cause the application to perform undesired operations.

Are these problems widespread?

We developed two tools for analyzing application code and detecting applications that are likely to be at risk for Intent leakage or Intent spoofing. These tools look for applications that improperly use implicit Intents for internal communication that should be private.

We tested 497 apps and found 115 possible Intent leakage vulnerabilities and 314 possible Intent spoofing vulnerabilities.

The "dangerous" applications above have Intent leakage/spoofing vulnerabilities which may be able to be exploited by a malicious application. For compatibility reasons, we could not test 10% of the applications for Intent leakage.

The vulnerabilities we addressed are quite common, and our simple changes to Android fixed many of them automatically. Furthermore, because our defense changed existing parts of Android rather than creating new parts, we had to do little to ensure that everything worked with the current system. Although backward compatibility is harder to test, the changes we made should maintain compatibility with most existing applications.

We can conclude that our improved Intents system is effective, easy to integrate into Android, and a step in the right direction.

Acknowledgments

Our thanks at Aerospace, for their technical expertise and constant support throughout the project, Joe Bresler, Jordan Alexander, Luke Parker, Adam Jackson, John Niles, Peter Reiter.

The research team at UC Berkeley whose ideas inspired and laid the foundations for our work: Erika Chin, Adrienne Porter Felt, Kate Greenwood, David Wagner.

Our faculty advisor, Geoff Kuenning, for his helpful advice and feedback at every stage of our project.
Silicon Wafer Conditioner (Engineering)

Rapid Silicon Wafer Temperature Conditioner Design

Team: Kirby Haraguchi (TI-Spring), Dalar Nazarian (TI-Fall), Niger Washington, Kevin Tham, Tiffany Liu (Spring), Matthew Kweon (Fall)
Liaisons: Steve Cui, Ph. D, Anoop George, Ph. D (Spring), KB Seong, Ph. D (Fall)
Advisor: Professor Adrian Rightower

Motivation
Cost-effective of the wafer manufacturing process is emphasized by the step in maintenance and each wafer quality by a clean silicon wafer. KLA-Tencor's new process project, project 1, is to develop a new process that can minimize the time and cost of wafer conditioning. The new process is to be implemented in the KLA-Tencor's facility to improve the wafer's quality and reduce the time of wafer conditioning.

Design
Multiple heating methods were compared using the following design criteria:

- Temperature uniformity across wafer after cooling for 50 minutes
- Power consumption
- Temperature increase after heating for 30 minutes
- Time to reach temperature
- Degree of maintenance

Methods Evaluated:
1. Radiation Heating
2. Thermal Immersion
3. Radiation Infra-Red Lamp
4. Convection
5. Radiation Infra-Red Lamp
6. Convection

Test Results
The prototype was tested on a wafer furnace at KLA-Tencor. The prototype was designed to heat the wafer to a specific temperature, 90°C, and to be mounted to the wafer furnace. Each wafer was heated for five minutes, and the heating method of each wafer, the wafer, and the time, were all recorded. The temperature measurements were taken at three different locations on the wafer, and the difference among these spots varied. The prototype was then tested in a more realistic environment. The wafer was placed in the prototype using a vacuum chamber, and the heating chamber was heated to the required temperature. The temperature distribution of the wafer was recorded by using a thermal image scanner, and the temperature profile was recorded by using a thermal image scanner. The temperature measurement was recorded by using a thermal image scanner, and the temperature profile was recorded by using a thermal image scanner.

Temperature Measurement
Conventional wafer heating: temperature measurement devices such as ultrasonic (US) thermocouples and thermal imaging cameras cannot be used on silicon wafers. This prototype allows low-cost results to determine the temperature and resistivity to the radiation (10-15). The prototype uses a thermal imaging camera to show the temperature profile.

Conclusions
The KLA-Tencor silicon clamp design has been tested and found to be effective in heating the wafer to the desired temperature. The prototype was designed to heat the wafer to the desired temperature, and the temperature profile was recorded by using a thermal image scanner. The prototype allows low-cost results to determine the temperature and resistivity to the radiation (10-15). The prototype uses a thermal imaging camera to show the temperature profile.

Acknowledgment
The KLA-Tencor silicon clamp design was found to be effective in heating the wafer to the desired temperature. The prototype was designed to heat the wafer to the desired temperature, and the temperature profile was recorded by using a thermal image scanner. The prototype allows low-cost results to determine the temperature and resistivity to the radiation (10-15). The prototype uses a thermal imaging camera to show the temperature profile.

References

IV Pump Control (Mathematics)

2005-2006 Cardinal Health Mathematics Clinic
Modeling and Control of the Next Generation of IV Pumps

Cardinal Health
Cardinal Health and the Alerts Product division seek to create a new generation of IV infusion systems that are more accurate, energy efficient, and compact than previous models. The Hybrid IV Infusion System diagrammed below has been proposed for this purpose.

Hybrid IV Infusion System
1. IV fluids bag
2. IV tubing
3. Pump device
4. Catheter
5. Motive Pump
6. Restrictor
7. Flow Sensor Channel
8. Flow Sensor
9. Control Algorithm

Problem Statement
Our task is to propose and develop a control algorithm for the above-demonstrated Hybrid IV Infusion System. It will quantify the flow sensor for the current flow rate and then adjust the restrictor and/or motive pump to maintain the desired flow profile. Our goal is to minimize power consumption while conforming to the specified accuracy goals.

Multiple Cylinders Model
To model fluid flow through the Hybrid IV Infusion System, we first derive the equation governing flow through a single cylinder assuming laminar Hagen-Poiseuille flow.

We can then model the system without the pump as a series of vertically aligned cylinders of varying height and radii. By modeling components in series, we can consider the resistance to fluid flow through each component. We then use these values to derive a flux equation. In order to have a complete, robust model of the system, we need to include the pump and better model the geometry of the restrictor.

Restrictor Model
The restrictor is a needle valve whose position is controlled by a DC gear motor. It consists of a conical needle which can be inserted into a conical flow channel to impede flow, or retracted out of the channel to allow greater flow. Below is a two-dimensional depiction of the needle valve, where x measures its position, and G is the gap through which fluid flows.

We previously modeled the restrictor as a single cylinder, but we can more accurately model the needle and channel as inner and outer conical cylinders, respectively. Thus fluid flows through gap G between the inner and outer cylinders, creating an annular flow region. We then find the resistance to flow in this annular region and incorporate it into the Multiple Cylinders Model as this restrictor resistance.

Pump Model
The pump consists of a single chamber and two one-way valves, one above and one below. The chamber expands, pulling fluid into the pump from above, then contracts, driving fluid out of the pump. The geometry of the chamber is complicated, and thus very difficult to model directly. Therefore, we model the pump as a black box; we fit data provided by Cardinal Health to model the pump's effect on fluid flow. We then combine this pump model, the restrictor model, and the Multiple Cylinders Model to find an equation of flow through the entire Hybrid IV Infusion System.

Control Algorithm
The goal of our controller is to deliver the correct amount of fluid to the patient, within an error tolerance of 1%. To facilitate correct delivery, we have control over two variables: the position of the restrictor's needle and the duty cycle to the pump. With two control variables, many configurations will produce the desired flow rate, and part of our task was to strike a balance that minimizes power consumption while remaining accurate. Our algorithm combines feedback and adaptive feedforward techniques to control these two variables with power consumption in mind.

Restrictor Control
Moving the restrictor gives us fine control over flow rate. To determine the most appropriate needle position, we combine the outputs of an adaptive feedforward controller and a feedback controller. The feedback controller determines the dependence of flow rate on restrictor position by taking successive readings from the flow meter, and outputs the restrictor position that it predicts will yield the desired rate. To eliminate accumulated error, we supplement this with the output from a PID feedback controller.

Pump Control
When conditions are such that opening the restrictor alone is not sufficient to obtain the desired flow rate, we must turn on the pump to increase downstream pressure. Our controller acts by incrementing or decrementing the duty cycle to the pump, using a number of heuristics to determine when it is appropriate. If the restrictor is wide open and flow is insufficient, we increase the pump activity; similarly, if the restrictor is closed beyond a certain threshold, we decrease activity. Additionally, our controller can shortcircuit these in an intelligent manner by predicting the maximum obtainable flow under a given pump regime, and effecting necessary changes in pump activity preemptively.

Performance Evaluation
In order to test the performance of the control algorithm and to facilitate further development, we have created a Graphical User Interface (GUI) to control the entire system in simulation. Through the GUI, users have access to the parameters that define a specific drug delivery scenario.

Results in Simulation
Even under many non-standard conditions, our control algorithm achieves the target accuracy goal. The following shows the results of a difficult scenario including both a change in flow rate and fluctuating bag height.

Deliverables
- Mathematical model of Hybrid IV Infusion System including individual models of all system components
- Control algorithm and all necessary m-files
- GUI with supplemental help files

Acknowledgments
Cardinal Health Liaisons
Boo Butterfield
Paul Dewey

Team Members
Sarah Mann (Team Leader), Hope Runyon, Susanna Ricco, Reid Howard

Faculty Advisor: Andrew Barnoff
Tagged-Neutron Calibration Source (Physics)

**Abstract**
The Physics/Engineering Clinic team has designed and constructed a waterproof tagged-neutron source that allows LLNL to measure the efficiency of their water-based neutron detector prototype.

**Project Statement**
- AmBe source emits neutrons in time-coincidence with 4.4 MeV gamma rays, which we detect with a Bismuth Germanate (BGO) scintillation detector, thereby "tagging" neutrons.
- Electronic circuit transmits a signal to the LLNL neutron detector when a neutron is "tagged."
- Tagged-neutron source must be robust, waterproof, and movable within the detection cavity with < 1.5 cm spatial resolution.
- Will be used by LLNL to measure the efficiency of their water-based neutron detector prototype.

**AmBe Source: Three Peaks**
- "Tagging" gamma rays are absorbed through pair production events which results in three peaks (4.4, 3.9, and 3.4 MeV).
- These three peaks correspond to the existence of a neutron.
  - A detection in this region produces a signal that indicates a coincident-neutron emission of the AmBe source.
  - The signal is sent to LLNL’s water-based detector.

**Design Validation with MCNPX**
- Monte Carlo N-Particle eXtended was used to calculate theoretical gamma ray capture for a scintillation crystal to evaluate design selections.
  - The dependence of gamma detection rate on crystal size was modeled.
  - A crystal with height and radius of 2” was chosen to balance efficiency with weight.

**Positioning Arm**
- A fixed-angle arm was chosen for operational simplicity. The arm covers the area shown in red.

**Final Design**
- Fixed-angle high-performance polyethylene positioning arm with aluminum reinforcement
- Coordinate measurement protocol for positioning the tagged-neutron source
- AmBe source
- BGO scintillation crystal
- Custom waterproof casing with O-ring
- Gamma ray detection signaling protocol

**Waterproof Casing**
- LLNL’s neutron detector uses gadolinium dissolved in water to capture and detect neutrons.
- A waterproof casing, sealed with a threaded plug and a rubber O-ring, protects the AmBe source, the BGO crystal, and the photomultiplier tube from the water.

Special Thanks to:
- Annie Atyeh
- Water Cook
- Mike Wheeler
- Dr. Steven Duszak
- Dennis Carr
- Engineering Staff
- Dr. Adam Bernstein
- Professor King
- Engineering Staff
- Dr. Steven Duszak
- Professor King
Prior Sponsor Recommendations Are Strong: You Can Ask Them

- **Becton, Dickinson and Company (BD):** Robert D. Butterfield, Research Fellow, Infusion and Respiratory Systems, (858) 617-5787

- **Honeywell:** James Van Ackeren, Manager, Performance Analysis, (310) 512-4832

- **Lawrence Livermore National Laboratory:** Adam Bernstein, Advanced Detector Group, I-Division, (925) 422-5918

- **Northrop Grumman Corporation:** Charles Volk, Vice President and Chief Technologist, (818) 719-7765
Prior Sponsor Recommendations Are Strong: You Can Ask Them (cont.)

- **Opto 22**: Mark Engman, President and CEO, (951) 695-3000
- **Oregon Biomedical Engineering Institute**: Kenton Gregory, President, (503) 216-5210
- **The Aerospace Corporation**: Joseph Betser, Senior Project Leader, Business Development, (310) 336-0577
Harvey Mudd College was first and still sets the standard

• Clinic gives Sponsor fresh ideas on an important problem
• Team of sharp, motivated and creative students working for a whole year
  • Joint projects across specialties common
• Many projects lead to patents
• Many results are implemented
• Many sponsors return in subsequent years
• Student recruiting opportunities
Project Areas

Engineering strengths in:

• General Engineering
• Biomedical Engineering
• Computer Engineering, Embedded Processors
• Systems & Signals, Controls
• Conceptual Design
Project Areas (cont.)

Computer Science strengths in:

• User Interfaces
• Data Mining
• Artificial Intelligence / Robotics
• Distributed Systems / Parallel Processing
• Algorithms
• Computer Vision
• Graphics / Visualization
• Computer Games
• Systems and Networking
Math strengths in:

- Operations Research/Statistical Models
- Algorithms
- Dynamic Models
- Bioinformatics
- Mathematical modeling and optimization
- Statistics and machine learning
- Fluid dynamics
- Numerical methods
Project Areas (cont.)

Physics strengths in:
- Nuclear
- Optics & E&M
- General Physics
HMC's Common Core Makes Our Students Even Better

- Calculus: Required prior to admission
- Mathematics: 3 semesters (multivariate calculus, linear algebra, differential equations, probability and statistics)
- Physics: 2-1/2 semesters with lab
- Chemistry: 1-1/2 semesters with lab
- Biology: 1 semester
- Engineering: 1 semester (systems engineering)
- Computer Science: 1 semester
- Writing: ½ semester (Intro to Academic Writing)
- Choice Lab: Emphasizing experiential learning
- Humanities, Social Sciences and Arts: 11 semesters
Global Clinic at Harvey Mudd College

Partnerships with universities and sponsors in Puerto Rico, Singapore, Iceland, India, Japan & Israel since 2006
Wastewater Treatment System Design (Global Clinic)

Wastewater Treatment in Rural China

Fred Johnson  Erin Partian  Cindy Scanlon  Claire Walker

Abstract
The Institute for the Environment (LIFE) works with individuals and communities in developing countries to produce appropriate and life-saving water, sanitation, and shelter technologies. The Nanyang Technological University and Harvey Mudd College Global Clinic team has undertaken the project of designing a wastewater treatment system for household use in the Jiaoyuan Village, in the Sichuan province of the People’s Republic of China. People throughout rural China, and other countries, collect their blackwater in large pits and dispose of the waste directly on their crops without treatment. This practice has led to millions of deaths worldwide. The team has evaluated the available options for blackwater treatment and is designing a composting system that will produce quality fertilizer while being easy to build and maintain in a local context.

Problem Statement
With the creation of the Three Gorges Dam and subsequent reservoir, China has had to face its new and present water issues, such as:
- Maintaining high water quality within the reservoir: This is critical in order to supply safe drinking water to a vast portion of China’s population.
- Dealing with wastewater from rural communities: China has built numerous wastewater treatment plants, but they are not economic on a small scale.

The team aims to devise a solution for rural wastewater treatment, focusing on the community of Jiaoyuan, located near the Three Gorges Dam. The goals for the design are:
- Reduce the pollution level of the river running through Jiaoyuan: Domestic greywater flows slowly along the river, and part of it is eventually deposited into the Three Gorges Reservoir.
- Increase the quality and safety of the waste to which the villagers are exposed: Blackwater is collected and treated in Jiaoyuan Village.

There is no collective wastewater treatment facility in the village. The Chinese government offers some solutions such as septic tanks and anaerobic digesters, but these systems cannot be implemented without assistance.

Jiaoyuan Village

- Village Statistics:
  - 812 households of 3-4 members per household
  - Total land area is 2 sq km, but total farmland is 1.44 sq km
- Crop grown include corn, sweet potato, beans, rice and other fruits and vegetables. They also raise pigs, chickens and ducks.
- Trash and pollutants collect in the Lianghe River that runs through Jiaoyuan.

Thermophilic Composting Latrines
The team has decided to use a Multrum composting latrine with several modifications for use in rural villages in China.
- Thermophilic processes instead of dehydration processes. This will decrease the time needed to produce safe fertilizer.
- A mechanical time-delay before the waste is made accessible. This will let the villagers know when the fertilizer is safe to be used on their crops.

The team is currently testing several aspects of this design.
- Construction of original Multrum composting latrines to test thermophilic processes.
- Mathematical and physical modeling to determine the exact dimensions and mechanics of the time-delay.

Jiaoyuan's Village:

Wastewater is collected in a manure pit built by individual families near the home toilet and the animal house to collect the blackwater from both sources. Blackwater is wastewater from toilets, containing human and animal feces and urine. Blackwater is distinct from greywater, which consists of domestic wastewater produced by activities such as washing, dishwashing, and laundry.

There is no collective wastewater treatment facility in the village. The Chinese government offers some solutions such as septic tanks and anaerobic digesters, but these systems cannot be implemented without assistance.

Implementation
To ensure that the final product will actually be utilized by the Jiaoyuan Village, the team will create a business plan for implementation that will include:
- Social considerations such as the daily activities of the villagers, customs regarding domestic activities and gardening, and openness to foreign involvement.
- Economic considerations such as costs for the villagers (including initial financing and maintenance costs) as well as the cost of education in presenting the new design to the village.
- Recommendations for the design based on differences in weather and average diet between Jiaoyuan and Claremont.
- General recommendations for alterations that will make the design applicable to other locations as well.

Deliverables
We will deliver the following to LIFE:
- Thermophilic composting latrine design.
- Constructed wastewater system for the Lianghe River.
- Solar powered water recycling plans for the Lianghe River.
- Business plan for implementation, operation and maintenance of the wastewater treatment system.

Acknowledgments
LIFE Liaison
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Thank you to Babcock Laboratories.
For More Information

https://www.hmc.edu/clinic

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The Year’s End: Projects Day

GoDaddy team's presentation
Year’s End: Projects Day

AmEx team’s dinner
and beyond...

AmEx team’s visit
The Year’s Start: Orientation Day

- Liaisons invited to campus
- Meet with Clinic Director
  - Strategies and tips
- Meet with team and faculty advisor
  - Cover problem in detail
  - Discuss confidentiality
- Establish communication routine
  - Email/Slack/other
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inside a weekly telecon