Clariant: The Social Printer
ME 310 Winter 2013 Documentation

University of St. Gallen

Alexandre Jais
Hao Jiang
Scarlett Si Jiang
Daniel Levick
Raphael Thommen
Timo Von Bargen
1 Executive Summary

Clariant is an international leader in specialty chemicals, an industry characterized by increasingly high competition. Recent global trends, including the low-cost production of specialty chemicals in emerging chemical markets, have dramatically increased competition for Clariant. To stay ahead of the competition, Clariant needs to develop new products and technologies that cannot be less expensively replicated by emerging markets. To this end, Clariant has founded a new business unit in printed electronics, an emerging industry that uses special inks to print electrical components directly onto various substrates. In order to thrive in this new and rapidly developing industry, Clariant requires the ability to quickly innovate to keep up with the cutting edge.

Our team, composed of four Mechanical Engineering masters students at Stanford University and two Business Innovation masters students at St. Gallen University in Switzerland, has been tasked to produce a new open innovation and communication platform for Clariant tailored to their new Printed Electronics business unit. During the first seven weeks of the project, we researched Clariant’s current innovation practices, investigated technologies that facilitate collaborative communication, and prototyped several platform ideas. The second eight weeks were focused on researching printed electronics, interviewing and defining target users, and prototyping subcomponents of the innovation system shown in Figure 1.

![Figure 1: Innovation System Diagram](image)

Our innovation system consists of four parts, identified in Figure 1 by color. The showcase event (green) is an industry gathering at which Clariant needs to make a strong impression. The web platform (blue) is a social network and online marketplace for printed electronics. The social meet-up (yellow) is an event centered around a design or innovation challenge. Finally, the collaboration machine (red) is a dual-purpose device that not only showcases Clariant’s technological prowess and forward thinking, but performs a useful function to facilitate collaboration. The goal of the system is to promote collaboration in a trustful, community-oriented way.

The most important element in the system is its users. Our system has three target user groups: startups, academics, and Clariant. Table 1 shows a summary of these users along with their needs as we identified them over the past eight weeks. There are two key findings...
of our need search: 1) there is a lot of mistrust in the PE community, especially among startups and 2) the primary way startups and academics say they form trustful relationships is via face to face communication. This mistrust seems to have limited the amount of collaboration within the industry and we see it as the major impediment to an open innovation community.

**Table 1: User Need Summary**

<table>
<thead>
<tr>
<th>User Group</th>
<th>Top Unmet Needs</th>
<th>Can Offer/Provide</th>
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<tr>
<td>Startups</td>
<td>• Find talent</td>
<td>• New technology</td>
</tr>
<tr>
<td></td>
<td>• Trustful collaborations</td>
<td>• New requirements</td>
</tr>
<tr>
<td></td>
<td>• Scale-up know-how</td>
<td>• User feedback</td>
</tr>
<tr>
<td>Academics</td>
<td>• Trustful collaborations</td>
<td>• Advanced PE tech</td>
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<tr>
<td></td>
<td>• Face to face communication</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Inks samples</td>
<td></td>
</tr>
<tr>
<td>Clariant</td>
<td>• Innovations</td>
<td>• Materials</td>
</tr>
<tr>
<td></td>
<td>• Earlier involvement in R&amp;D</td>
<td>• Clariant expertise</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Clariant networks</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Market intelligence</td>
</tr>
</tbody>
</table>

To combat mistrust, we believe that our innovation system must incorporate the showcase event and social meet-up subcomponents to serve as venues for face to face interactions. We also believe that the collaboration machine serves an even more important function: it encourages users to collaborate in an application-oriented environment (the social meet-up) that builds relationships around team application goals instead of business transactions.

Our most promising idea for the collaboration machine is the 3D surface printer for printed electronics, capable of printing functional inks on any 3D surface. We believe this device will allow the PE community to prototype the next major applications of printed electronics. Figure 2 shows an initial prototype, capable of printing patterns on a cylinder.

![3D Surface Printer Prototype](image)

*Figure 2: 3D Surface Printer Prototype*

Over the next 7 weeks, we will construct a high resolution prototype of the 3D surface printer and test it at a social meet-up event with real users. We hope to measure an increase in profile creation and messaging on our web platform, as well as generate application ideas and designs that will shape the future of printed electronics and Clariant’s role in it.
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**Glossary**

**B2B:** Standing for Business-to-Business, it describes commerce transactions between businesses, such as between a manufacturer and a wholesaler, or between a wholesaler and a retailer.

**B2C:** Standing for Business-to-Consumer, it describes commerce transactions between a manufacturer and an end consumer.

**Commodity Chemicals:** Low cost and widely used chemicals which could be accessed easily in everyday life, such as alcohol and oil.

**Closed Innovation:** Innovations or ideas generated inside a company, i.e., within its employees.

**Differentiation:** A corporate strategy stating that to win market shares you have to be different from your competitors.

**Fast prototyping:** In a certain situation to build or duplicate a prototype as fast as one can. It is sometimes also called rapid prototyping.

**Low-cost Leadership:** A corporate strategy to gain a leader position on a market with very low cost products.

**Open Innovation:** Innovations or ideas generated outside a company, such as other collaborative companies or end consumers.

**P&G:** Standing for the Procter & Gamble Company, it is an American multinational consumer goods company headquartered in downtown Cincinnati, Ohio, USA. Its products include pet foods, cleaning agents and personal care products.

**PE:** Printed Electronics

**REACH:** A regulation system in Europe to restrict harmful chemicals. It stands for Registration, Evaluation, Authorization and Restriction of Chemical.

**Specialty Chemicals:** Chemicals for specialty usage, which could rarely be accessed in everyday life, such as masterbatches. Specialty chemicals are the opposite of commodity chemicals.

**StartX:** A non-profit organization whose mission is to accelerate the development of Stanford's top entrepreneurs through experiential education.

**Tangible Open Innovation:** It is a category of open Innovation that is not web-based, instead, it is physical and tangible.

**VC:** Venture Capitals, Investors for startup firms and small businesses with perceived long-term growth potential.
2 Context

2.1 The Design Team

2.1.1 Stanford Group

**Hao Jiang**
Status: 1st Year M.S. in Mechanical Engineering
Contact: jianghao@stanford.edu
Skills: lathing, milling, CNC processing, craft planning, mechanism design, mechatronics.
Computing: Solidworks, AutoCAD, C, MATLAB, Linux

I come from the northeastern part of China. I acquired my Bachelor Degree from Beijing University of Aeronautics and Astronautics, focusing on Manufacturing, Design and Robotics. I really like doing innovative design work and collaborating with people on projects. I am interested in playing acoustic guitar and table tennis (ping pong). And I am also fascinated in Chinese cuisines. I am looking forward to making friends with more people and pursuing our dreams!

**Alexandre Jais**
Status: 1st Year M.S. in Mechanical Engineering
Contact: ajais@stanford.edu
Skills: solid and fluid mechanics, simulation, rapid prototyping, mechatronics
Computing: C, C++, Python, Maple, MATLAB, Spaceclaim, Solidworks, CATIA, SIMULINK, Dr Frame 3D, Comsol Multiphysics, Adobe Lightroom, Adobe InDesign, Ableton Live, Max MSP

I was born and raised in the wonderful city of Paris in France (Ah Paris...) and studied at Ecole Centrale Paris. My adventure in Stanford started in September 2012 and my interests include Biomechanics, a bit of Robotics and of course Product and System Design here at Stanford.
I am a guitar player, a passionate reader and an amateur photographer.
Scarlett, Si Jiang
Status: 2nd year M.E. Graduate Student
Contact: jiangsi@stanford.edu
Skills: PCB design, signal processing, MEMS design
Computing: C, R, AutoCAD, Altium Designer, MATLAB

I grew up in a village near deserts in Xinjiang Province, the most western part of China. I graduated from Tsinghua University with a Bachelor Degree of Micro-Electronic-Mechanical-Systems. I keep exploring all kinds of possibility of my life, and I am glad to pursue entrepreneurship after graduation. I admire freedoms, the love of people, animal and nature.

Daniel Levick
Status: 1st year M.E. Graduate Student
Contact: dlevick@stanford.edu
Skills: mechatronics, thermal design, rugged design, systems integration
Computing: Solidworks, Solidworks Flow Simulation, Inventor, MATLAB

Born and raised in the Virginia suburbs of D.C., I earned a B.S. in Mechanical Engineering from the University of Virginia in 2010 and worked for two years at a satellite communications firm before coming to Stanford in 2012. I enjoy robots, singing, and singing robots. I also enjoy traveling. My most enjoyable product design experiences have been those that integrate electronics, software, and mechanical design. I am very excited to be studying at Stanford and learning to be a better designer from ME310.
2.1.2 St. Gallen Group

Raphael Thommen
Status: Masters Candidate in Business Innovation
Contact: raphael@thommen-sissach.ch
Skills: communication & media relations, business innovation, marketing, business engineering
Computing: Microsoft Access, Micro Strategy, PowerPivot

I was born in Basel, Switzerland. I received my B.A. in Business Administration from St. Gallen University. I have enjoyed internships at a local newspaper and at Credit Suisse and Swisscom. I also enjoy handball, tennis, journalism, and cooking.

Timo von Bargen
Status: Masters Candidate in Business Innovation
Contact: timovonbargen@web.de

I was born in Ulm, Germany. I received a B.S. in Business and Economics from University of Hohenheim. I have experience from internships at Daimler AG & EnBW AG. I enjoy music, sports, and travel.

2.1.3 Coach: Dr. Vinod Baya
Contact: vinodbaya@gmail.com

2.1.4 Clariant Liaison:

Dr. Hans-Tobias Macholdt
Clariant International Ltd., Switzerland
Group R+D - R&D Center Colorants - Technology Scouting
Email: HansTobias.Macholdt@clariant.com
Phone: +49-69-305-2079
Fax: +49-69-331749
2.2 **Corporate Partner: Clariant**

Clariant is a global leader in specialty chemicals. Specialty chemicals are high value, relatively low production volume chemicals designed for a specific purpose. For instance, Clariant produces a line of chemicals for tanning leather. It also designs and redesigns chemical processes, such as the chemical process for dying blue jeans. Clariant sells its chemicals and processes to business customers that use Clariant’s products to produce finished goods for end consumers.

2.3 **The Need for Rapid Innovation**

Recent global trends have dramatically increased competition for Clariant. A major reason for this increase is the low-cost production of specialty chemicals in emerging chemical markets. See Appendix A for a detailed analysis of the chemical industry and Clariant’s specific challenges. To stay ahead of the competition, Clariant needs to develop new products and technologies that cannot be less expensively replicated by emerging markets. In order to address this need, Clariant requires the ability to rapidly innovate.

Clariant’s innovation practices are currently defined by an inward focus. Only one organization within Clariant appears to communicate directly with customers: the business development unit. The business development unit conducts market research in order to generate requirements and ideas for possible innovations. Otherwise, innovations are born in Clariant’s R&D labs. See Appendix B for a description of current innovation practices.

The concept of open innovation holds great potential for improving Clariant’s ability to innovate. Open innovation attempts to augment traditional market research by interactively capturing needs and ideas from all possible stakeholders and interested parties. The goal of open innovation is to transform innovation networks by not only adding innovation partners but by improving lines of communication between innovators. Most importantly, openness and improved communication could create a sense of community and trust that not only will benefit Clariant, but could make the entire industry more efficient and creative.

2.4 **A New Business Unit: Printed Electronics (PE)**

At the end of January, Clariant informed us that we would apply our innovation solution to their new printed electronics business unit. Printed electronics (PE) is a revolutionary new technology that uses special inks to print electronic components using traditional printing technologies like inkjet, screen printing, and gravure. Current PE applications are relatively limited. Because the new business unit will be a newcomer to a small but rapidly developing industry, it will have an even greater need to reach out beyond Clariant’s R&D labs into the broader community to form partnerships and collaborations with key players. While Clariant claims to have an excellent network of business partnerships with key players in the printing and electronics industry, these will not necessarily be the key players in the printed electronics industry. To thrive, Clariant’s new business unit must be able to identify, collaborate with, and eventually become one of these key players.
2.5 Problem Statement

Our task is to fulfill Clariant’s need to rapidly innovate by providing them with an open innovation solution targeted at the printed electronics industry. This solution must overcome several major challenges:

1. Lack of awareness: Many potential innovators have never heard of Clariant. This will be even more applicable in the printed electronics industry because Clariant does not currently sell any PE products. It is impossible to include these potential innovators in Clariant’s innovation network without first introducing them to Clariant’s products and values.

2. Lack of trust leads to lack of collaboration: One of the major benefits of PE technology is that its materials and manufacturing methods are very inexpensive. Therefore protecting intellectual property (IP) becomes essential for business success. Fear of IP theft breeds mistrust and severely limits the opportunities for collaboration.

3. A unique incentive: Potential innovators and emerging key players in the PE industry need an incentive to collaborate with Clariant. Clariant has expressed to us that this incentive cannot be acquisition or venture capital. Many other incentives that Clariant could provide, like market intelligence and scale-up process knowledge, are not unique and could be provided by competitors.

Our solution must overcome these barriers in order to add the highest potential innovators to Clariant’s innovation network. Several opportunities exist that we believe will help to meet these challenges:

1. Trust as an incentive: Trust is incredibly valuable in the PE community. If Clariant can gain the trust of innovators, this could be a major incentive for collaboration.

2. Rapidly growing application space: The first PE products are only just coming to market. Most of the hype is focused around flexible OLED displays. This means that there is very little market “pull” for most PE inks at the moment. We see a huge opportunity to imagine and create new applications that will generate this market pull for the benefit of the entire PE industry. Furthermore, there is evidence that exciting applications are powerful incentives for collaboration.
3 Design Requirements

Through benchmarking and prototyping we refined our initial problem statement into more specific functional, physical, and business requirements. Because our given problem statement is very broad, many possible future requirements are presented as opportunities.

3.1 System Description

The system consists of four components:

1. Social Meet-ups (yellow): this is an event in which the users can meet and interact outside the context of their own companies or endeavors in order to form trustful relationships and generate new application ideas.
2. Showcase Events (green): these events are primarily for introductions and advertising. One example is PE conferences.
3. Web Platform (blue): an online community that lets users explore and maintain contact with the PE industry.
4. Collaboration Machine (red): this is device or product that can be used to showcase Clariant’s unique value proposition as well as perform useful functions that facilitate collaboration. For instance, the device would be brought to showcase events to generate hype, and then brought to social meet-ups to provide a unique function to enhance collaboration.

3.2 System-Level Functional Requirements

Table 2: System-level functional requirements

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<th>Requirement</th>
<th>Metrics</th>
<th>Rationale</th>
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<tr>
<td>Attract desirable users</td>
<td>Desirable users are defined as those that can generate useful ideas or provide other important services to the PE</td>
<td>According to our interviews, it is extremely important to not only attract users to our system but to filter them in</td>
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community, as judged by the community itself. Desirable users of the system, as measured by number of web platform profiles, should be maximized.

some way to eliminate people just out to steal IP. The idea of a somewhat exclusive PE community was well received.

<table>
<thead>
<tr>
<th>Raise awareness of Clariant’s brand and capabilities</th>
<th>Survey of users indicates a statistically relevant increase in user awareness of Clariant’s brand and capabilities</th>
<th>Addresses lack of awareness problem (see problem statement)</th>
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<td>Connect users to each other and to Clariant</td>
<td>Use web platform metrics to indicate user network connectivity. The majority of users’ number of other user profiles visited should increase with time at a rate of at least 1 new visit per week.</td>
<td>A good first step in building a community is to make its members aware of each other.</td>
</tr>
<tr>
<td>Increase user-user and user-Clariant collaboration</td>
<td>Number of collaborations between these groups should measureable increase.</td>
<td>User-Clariant collaboration is the goal of the system given by Clariant. We believe that promoting user-user interaction will generate trust in Clariant and in the system because it is more altruistic.</td>
</tr>
<tr>
<td>Generate innovation</td>
<td>We will attempt to measure this at a social meet-up event by surveying a team of experts from Clariant. The goal is to have the majority of the ideas generated at the event to be judged as “wow” ideas.</td>
<td>This requirement was given by Clariant.</td>
</tr>
</tbody>
</table>

**System-Level Assumptions**

- The internal culture at Clariant is prepared to shift to open innovation (especially at the top management level).
- Clariant is willing to implement such a system provided it is convinced of the system’s ability to enhance its innovation practices.
- The technology to satisfy these requirements exists.

**System-Level Constraints**

- Prototyping the system must remain within budget
- The final solution must minimize cost to Clariant
3.3 **Subsystem Functional Requirements**

3.3.1 **Web Platform**

**Functional Requirements**
- Provide metrics of system success including number of profiles, search heuristics, and message rates.
- Allow users to contact each other
- Give a holistic picture of the PE community – who has/ knows what
- Get people to share information about themselves openly
- Establish a basic level of trust between users just by being on the system

**Opportunities**
- Interviews have indicated a need for a clearinghouse function that validates PE products independently. This would be a great feature to add to the community.

3.3.2 **Showcase Events**

**Functional Requirements**
- Attract desirable users (as defined in the system requirements section).
- Promote our system and Clariant’s product and brand, measured through awareness and opinion surveys as well as a measureable increase in web platform usage after each showcase event.
- Initiate relationships. A minimum proportion of users that attend the event and have web platform profiles message each other or visit each other’s profiles.

**Physical Requirements**
- Large room with areas for mingling, large presentations, and product demonstrations.
- Accessible location for a large number of target users.

**Opportunities**
- Interviews have shown that the most common way to initiate trustful and useful collaborations is face to face (F2F) interaction. If Clariant can create a big impact at a large showcase event, they maximize their chance for interactions with people excited about their products.

3.3.3 **Social Meet-up**

**Functional Requirements**
- Attract desirable users (as defined in the system requirements section).
- Promote our system and Clariant’s product and brand, measured through awareness and opinion surveys as well as a measureable increase in web platform usage after each showcase event.
- Create trustful relationships.
- Generate new ideas for applications and new requirements for inks.

**Physical Requirements**
- Large room with areas for mingling, large presentations, and product demonstrations.
- Prototyping equipment for printing electronics and creating application prototypes.
- Accessible location for a large number of target users.

Opportunities
- Attract innovators from outside of the PE community that might never otherwise be encountered by PE users. These innovators could be doctors, artists, engineers, etc. that could drive application innovation.

3.3.4 Collaboration Machine

Assumptions
- Clariant has the ability to build the collaboration machine.
- Clariant has technical staff that can handle the technical problems of the collaboration machine or will partner with other companies that do.

Functional Requirements

Table 3: Collaboration machine functional requirements

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Metrics</th>
<th>Rationales</th>
</tr>
</thead>
<tbody>
<tr>
<td>The collaboration machine should be</td>
<td>More than 80% of the Printed Electronics people show that it is useful</td>
<td>Usability is the top priority of the collaboration machine.</td>
</tr>
<tr>
<td>useful enough to promote rapid</td>
<td>in a survey after trying the machine or watching the video of the machine</td>
<td></td>
</tr>
<tr>
<td>prototyping, especially for Print</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The collaboration machine should be able to promote collaborations between people from startups. After demonstrating the machine in a showcase event and further letting people try it, there should be at least 30% of growth in collaboration contracts signed. The ultimate goal of the whole platform is to promote ideas sharing.

| ed Electronics people. | fulness, the machine cannot be either attractive or promoting collaborations. |
universities/research institutes, and Clariant. As a part of the whole system, the collaboration machine should also contribute to the...
The collaboration machine should make the whole platform unique enough that it is hard to duplicate in a short period of time.

The machine should have some features that current industry and research field do not. It should be at least 2 years before other competitor companies can duplicate it.

If the machine is easy to duplicate, then the platform loses attractiveness to a large group of people.
<table>
<thead>
<tr>
<th>The collaboration machine should show the advantages of Printed Electronics, like flexibility and Cla...</th>
<th>The machine should show at least the advantages of flexible circuits, thin substrates, and suitableness for mass manufacturing. Besides these, the more the better.</th>
</tr>
</thead>
<tbody>
<tr>
<td>and Clariant will also lose many potential collaborators and innovators.</td>
<td>Printed Electronics is a new technology and not yet well accepted</td>
</tr>
</tbody>
</table>
by people in the industry and research field. Thus the machine should show people the advantages and potential of Printed Electronics technology.
<table>
<thead>
<tr>
<th>The collaboration machine should be attractive enough to make people interested in the showcase event.</th>
<th>In a survey subsequent to the showcase event, at least 70% people should indicate that this machine is “cool” or “really cool,” and they’re willing to use it in future collaborations and rapid prototyping.</th>
</tr>
</thead>
<tbody>
<tr>
<td>One of the goals for the showcase event is to attract as much attention as possible. Thus as the key component of the showcase event, the machine sho</td>
<td></td>
</tr>
</tbody>
</table>
The collaboration machine should be portable so that Clariant can easily transport it to different showcase events, conferences so that 2 people can easily transport it on a vehicle. It is reasonable that Clariant will hold a lot of conferences and showcase events for brand use to arouse the interest of a large group of people.
Functional Constraints

- The Printed Electronics circuit and components have low performance and resolution.
- Printed Electronics people may not be experts in CAD modeling, thus the user interface of the collaboration machine (e.g. CAD modeling) should be simple and intuitive.

Functional Opportunities

- Clariant has premium inks so that the collaboration machine can make use of them to make the system unique and attractive.
- Clariant has good connections with other big companies, such as HP, that can help them manufacture and improve the collaboration machine.

3.4 Subsystem Physical Requirements

3.4.1 3D Surface Electronics Printer

Assumptions

- The 6 Degree-of-Freedom robotic arm is highly controllable and precise enough for the motion planning and control of the printhead and the printing object.
- Different functional inks can be printed with the inkjet printhead to produce circuit components and conductive layers.

Physical Requirements

Table 4: 3D surface printer physical requirements
| The surface printer should be able to print functional conductive inks on different substrates to make circuit components and conductive layers. | With the current most common paper-based or plastic film-based substrates, the printed circuits should show good conductivity to light up an LED with a proper power supply. | Conductivity is the most basic function of electronic circuits. Different applications require different substrates. Thus the printer |
| The surface printer should have a good control algorithm for the motion of the printhead | For the control algorithm, there should be zero steady state error. And the system should have a good estimation of the mass, inertia, and nonlinear forces to better facilitate the control. It also should not be computationally expensive. | The motion control of the printhead and printing object is the |
team and printing object, such as PID control.

critical part of the printer. The performance of the circuits is also largely dependent on how well and precise the trajectory can...
| The surface printer should be able to move the printhead and printing object with a certain amount of inertia. | The printhead or printing object within 2kg, the control and actuation system should be able to precisely control the motion of the printhead or the printing with 5% error. | Th printer should be robust enough so that it is suitable for different prototyping occasions and applications. |
The distance should be within 5mm.

For inkjet printing, large distance between the printhead and the printing object leads to poor printing results.
The cleaning/washing system should keep the printhead always able to print smoothly on the object.
Physical Constraints
- The 6 Degree-of-Freedom robotic arm is very heavy, which is not good according to the functional requirements.
- Inkjet printing relies on gravity, which makes it more difficult to rotate the printhead than the printing object.

Physical Opportunities
- The team could use the PUMA 560 arm in the course CS225A to work on the control algorithm implementation.
- HyeRyoung Lee from Material Science and Engineering is a PhD candidate in Printed Electronics field, and she can help the team with printing method and material choosing.

3.4.2 Web Platform

Assumptions
- People are willing to share their basic personal information in expertise and needs.
- People are willing to share their ideas and engage in academic and industrial collaborations given the right incentives.

Physical Requirements

Table 5: Web platform physical requirements

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Metrics</th>
<th>Rationales</th>
</tr>
</thead>
<tbody>
<tr>
<td>People should be able to have fast access to the web platform, and the transition between different web pages should also be</td>
<td>The waiting time for project configuration part should be less than 3 seconds. Online videos should have good</td>
<td>Long time for waiting will reduce people’s interest, and thus Clariant will lose a large group of innovators and collaborators.</td>
</tr>
<tr>
<td>Physical Constraints</td>
<td>Business Opportunities</td>
<td></td>
</tr>
<tr>
<td>----------------------</td>
<td>------------------------</td>
<td></td>
</tr>
<tr>
<td>The project configuration tool should include enough clear choices that people can easily choose and participate in the projects.</td>
<td>High potential innovators could also be high value potential customers. Adding them to Clariant’s innovation network could easily equate to adding them to Clariant’s customer network.</td>
<td></td>
</tr>
<tr>
<td>The matching and filtering part of the platform should be accurate enough that people can easily find other people that they want to meet and collaborate with.</td>
<td>The matching, filtering, and configuration part is the critical part of the platform. Whether people are willing to engage in the subsequent collaborations is largely dependent on whether the configuration is accurate and satisfactory enough.</td>
<td></td>
</tr>
<tr>
<td>There should be an online chatting or Email interface that Clariant could respond to questions and requests quickly and conveniently enough.</td>
<td>Fast response will make people feel paid attention to, and more engaged in the collaboration platform.</td>
<td></td>
</tr>
<tr>
<td>There should be an interface that Clariant can do certain statistics for current registered users and idea sharing.</td>
<td>The statistical data is convenient for Clariant to make decisions and adjustment for the next step collaborations.</td>
<td></td>
</tr>
</tbody>
</table>

Currently the team does not have information on Clariant’s specific Printed Electronics products and expertise, which is really useful for the website target users.

- The team does not have much expertise in website building.

**Physical Opportunities**

- The team can hire Computer Science students to help code and build the website.
- The team has access to many potential target users for internal tests, which will help the configuration process to be more accurate.

### 3.5 Business Opportunities

- High potential innovators could also be high value potential customers. Adding them to Clariant’s innovation network could easily equate to adding them to Clariant’s customer network.
• Creating an internal open innovation network could create the corporate cultural shift that is necessary to effectively execute external open innovation. This internal network could serve as a pilot and launch point for external open innovation. To create this internal network, our system could be prototyped inside the company between the new PE unit and related business units or personnel.

• Incorporate privacy functions that allow the creation and maintenance of Non-Disclosure Agreements within our system. In a competitive business climate, this may increase the chance that another business will partner with Clariant.
4 Design Development

4.1 What is Printed Electronics?

Printed Electronic is a set of printing methods that use common printing equipment or other low cost equipment (e.g. screen printing, gravure, or inkjet) to print electrically functional electronic or optical inks on various substrates, creating active or passive devices.

The value of Printed Electronics is derived from two main factors [17]:

1. Form Factor
   - Thin, Flexible, Lightweight
   - Minimally invasive (portable)
   - Wearable

2. Scale
   - Intrinsic size of a device: Where silicon would become expensive or impossible: e.g., to fit a body part
   - Distributed functionality: Where the area over which the desired function occurs is so large that assembly would become difficult or expensive: to sense and control large environments.

Printed electronics is expected to facilitate widespread, low-cost, low performance electronics applications. This is verified by significant demand for typical promised applications of printed electronics: [17]

- Printed interconnects (lead ware)
- In-mold circuitry
- Sensors / lab on chip replacement
- Components (integral and peripheral)
- Optics: displays, indicators, imagers
- Hybrid solutions (combination of printed and conventional)
- Function: heat, light, sound, force (sense and generate)
- Intelligent packaging:
  - RFID (radio-frequency identification) for asset tracking and freshness insurance (environment sensing for smart packaging)
  - Cold chain / tamper evidence / tamper proof packaging
- Medical, wearable diagnostic, therapeutic, monitoring devices

4.2 Printed Electronics Market Analysis

4.2.1 Market Overview

Printed electronics is a relatively young industry with a little over 10 years of history. It covers a range of technologies, including many enabling materials and technologies, each at very different points of maturity. Table 6 describes the top current applications of printed electronics. Very few printed electronics applications are currently profitable. Profitable applications are dominated by large corporate players, whereas many smaller players have gone out of business as shown in Figure 4 [16].
Despite its small number of current applications, printed electronics is projected to grow by almost $60 billion in the next decade, as shown in Figure 5. The vast majority of this growth is dependent on OLED displays. Other up-and-coming technologies are listed below:

Hot technology sectors [16]:
1. Metal oxides (for OLED TFT backplanes)
2. Graphene (supercapacitors becoming the biggest near term opportunity)

3. Printed silicon for selective PV emitters and NFC

4. Flexible barriers – including flexible glass

5. Transparent Conductive Films – a $1.8 Billion market, used in TFPV, displays, touch screens, solid-state lighting, etc. Options include CNT, graphene, nanoparticle ink, silver nanowires, PDOT...

6. Stretchable electronics, particularly for use in healthcare and applied to textiles

**PE industry 2013-2023 Forecast** ([www.IDTechEx.com/pe](http://www.IDTechEx.com/pe)) [16]

![Figure 5: Market overview Printed Electronics](image)

### 4.2.2 Business Strategies

Since a wide range of technology improvement is covered in the PE field, there are several different business strategies for different commercial markets [16]:

1. Replace whole existing devices: usually needs large investment, high risk, and high reward for a few companies to reposition.
   - OLED displays lighting: OLED (organic light-emitting diode) lighting can be a good replacement of traditional bulbs and liquid crystal displays.
RFID: Radio-frequency identification (RFID) is a wireless non-contact system that uses radio-frequency electromagnetic fields to transfer data from a tag attached to an object, for the purposes of automatic identification and tracking.

Figure 6: AcuityBrands is a major producer of OLED lighting solutions

Figure 7: RFID tags could replace barcodes

2. Improve something:
- Cost reduction (use less material or cheaper materials)
- Better performance, e.g. flexibility

Figure 8: Flexible, flat, and cheap wide area sensor matrix

3. Create a completely novel product:
   - Usually involves downstream to conceive and create complete solutions, such as the e-reader

Figure 9: Example of active e-paper
4.2.3 Printed Electronics Success Stories

Billion Dollar Success Stories [16]

1. E-readers (electrophoretic displays) - created a multi-billion dollar market including content in a few years.

![Various E-readers](image1.png)

Figure 10: Various E-readers

2. Conductive ink – metallic flake inks for bus bars and “fingers” for Photovoltaics – rapid increase in the past five years to a multi-billion dollar market for conductive ink. Nanoparticle ink is increasingly being adopted as well.

![Examples of metallic inks- aluminum ink](image2.png)

Figure 11: Examples of metallic inks- aluminum ink

3. OLED Displays in cellphones, portable electronics and (very) soon- televisions. Driver: better performance leading to product differentiation. The OLED display industry is projected to grow to $60 billion in annual sales in just ten years, as shown in Figure 13.
There are three anticipated waves of OLED displays entering the market:

a. Cell phone displays: 2010 onwards:

b. OLEDTV: 2013/14 onwards

c. Printed OLEDTVs: as soon as 2016

4.2.4 Selected Emerging Technologies

OLED Lighting

OLED lighting is low cost and the industry is growing rapidly. Products are beginning to be flexible and better as diffuse light sources. Currently only small quantity, premium priced lamps, panels, and experimental design kits are being produced on pilot production lines. Cost is coming down rapidly.

Key OLED Lighting Challenges include:

- Investment for larger area manufacturing
- Yield improvement
- Material cost reduction (particularly glass, edge barriers etc.)
- Availability and cost of flexible barriers
- Differentiated product design and marketing from LED lighting

Excerpt from an OLED lighting company website:

“The Acuity Brands OLED design center is passionate about OLED lighting. To us, working with OLED goes beyond simply thinking about a new light source. OLED has personality - we see it as collaboration between lighting and architecture where we can capture the essence of OLED and transform it into emotion, interaction, and illumination that is not only useful but also human. Our team has traveled the globe to share and celebrate these new approaches to lighting.”


Graphene

Graphene, the single layer carbon based material, is transparent, flexible, and has excellent electronic properties. It is a strong candidate for ITO replacement. ITO is currently used in LCD, PDP, and OLED displays, as well as silicon thin film solar cells, dye-sensitive solar cells, transparent electrodes, and IR shielding.

As it is called “the dream material,” graphene holds the potential for innumerable applications, as shown in Figure 15. It is a material that still requires consistent research and at the same time it is a material that is projected to grow substantially in the near future, as shown in Figure 16.
Figure 15: Graphene applications forecast 2012-2020[20]

Figure 16: Graphene market prediction 2012-2018[20]
Excerpt from a graphene company website:

Graphene Frontiers, founded in 2011, is a technological start-up based on new graphene-production technology developed at the University of Pennsylvania. With innovative technology that will to enable the continuous production of uniform, meter length single layer graphene films, Graphene Frontiers is dedicated to providing custom graphene solutions at a commercial scale – and an affordable cost. The science behind the technology is a cheaper and more consistent method of manufacturing graphene, the Nobel Prize-winning nanomaterial with unbeatable strength and conductivity. The new method aims to manufacture large sheets of graphene at room temperature and pressure, unlike the extreme conditions necessary in other CVD techniques. The result is easily manufactured, controllable roll-to-roll graphene sheets that can be custom tailored to a variety of uses. [http://graphenefrontiers.com/about-us/about-us/](http://graphenefrontiers.com/about-us/about-us/)

Applications of Conductive Inks

Figure 17 shows the five top emerging applications for printed conductive inks ranked by projected market value:

1. Photovoltaic (PV) is biggest user.
   - Thinner solar panels may necessitate a move away from screen to inkjet printers.
   - Low cost, high conductivity, narrow traces are required.
2. Biosensors – glucose test strips, ECG
3. Other - includes touch surfaces (e.g. automotive capacitive touch)
4. Indium Tin Oxide (ITO) replacement - lower end consumer electronics & flexible devices will be initial adopters
5. Smart packaging
Excerpts from two conductive ink company websites:

**EMD Chemicals** has a long-term commitment to organic photovoltaic [21]
1. A strategic partnership is in place with Nano-C for PCBM supply and active R&D on novel fullerene molecules (acceptor)
2. Strong progress in polymer (donor) development is being made at PCE moving beyond 8%
3. Ease of processing from non-halogenated solvents
4. Attractive blue color
5. New polymers in pipeline show higher potential for increased PCE Additional opportunities exist for materials in organic photo detectors

With Lisicon®, EMD Chemicals offers ready-to-print formulations of modern organic semiconductor materials for organic photovoltaics (OPV). Because these polymer materials can be processed as liquid solutions, a wide range of printing processes are suitable for the production of cost-effective organic solar cells: spin coating, ink-jet printing and roll-to-roll processes such as gravure and flexo printing.

EMD Chemicals offers, with Lisicon®, complete material solutions in the organic electronics (OE) sector for organic thin-film transistors (OTFT) in display applications as customer-specific and ready-to-print formulations. The range stretches from printable high-performance semi-conductors and dielectrics to surface treatment chemicals. They are also suitable for the production of backplanes as needed for flexible displays such as e-paper.
Silevo is a solar cell innovator and photovoltaic (PV) solar module manufacturer that has evolved the use of silicon for solar to offer cost-effective high performance solar modules. The company was founded on the principal that an evolutionary silicon solar cell technology can enable rapid acceleration of grid parity and widespread solar adoption.

Silevo is the first company to commercialize a ‘tunneling junction’ solar cell, a hybrid technology which couples the best attributes of 3 different materials (1) N-type crystalline substrate, 2) Thin Film Passivation, 3) Semiconductor oxide to optimize cell and module performance while limiting costs. Silevo’s breakthrough cell innovation coupled with traditional crystalline silicon (c-Si) package techniques enable Silevo’s Triex modules to optimize all three performance indicators in order to deliver the industry’s best value.


### 4.2.5 Common Problems and Challenges

Most applications need logic, displays & power. There are several impediments to delivering these requirements:

- Lack of component companies offering complete customizable solutions for end users i.e. where do I go to have a custom display (including driver electronics)?
- Lack of system integrators/solution providers, and those that do this face hurdle of IP concerns, compatibility issues, managing many component providers etc.
- Basic hardware platforms help to create volume - no use of programmability or modularity so far and printed electronics products are still built from scratch.

### 4.3 Users

From the design prompt we identified three targeted user groups for our design platform: Startups, academic researchers, and Clariant itself. Startups and academics are both idea generators, whereas Clariant can provide large corporation knowhow, networks, and market analysis.

#### 4.3.1 Startups

We interviewed several companies, C3Nano, who sells inks; Solicore, which sells flexible batteries, and StartX, an accelerator for startups. C3Nano and Solicore are fairly representative printed electronics startups. From the interviews it is clear that these startups’ greatest unmet needs are finding new talent to hire, trust, collaborations, and the ability to scale up.

For the startups, protecting Intellectual Properties issues are important. From the technical point of view, they place an extremely high value on acquiring the best talent they can find. It is generally harder for startups to hire people than big corporations. Each of the employees
needs to function efficiently and often at less pay than at a big corporation due to limited funding. Generally they go to universities and academics to search for talent. They would benefit from network to effectively search for the right people to hire.

From the business perspective, they also need trustful collaborations. The printed electronics industry is not well organized yet and there is a lot of mistrust within the community. Protecting intellectual property is essential to them, so trust must be established before starting collaborations with others.

Once the trust is built, they need a wide range of technology and process knowledge from partners and collaborators. Startups need market intelligence and knowledge about how to scale up. They also need technology and manufacturing-level assessment. From the interviews, it seems that startups usually pay for the third party consulting firms, mostly because they are the cheapest option. Other big companies in the field may also provide these scale-up knowledge, sometimes even more accurately, but generally have higher prices than those of consulting firms, and due to conflicts of interest, startups do not trust big companies.

Startups are good at capturing the vision of the industry and finding unique ways to meet customer needs. At the same time, by creating unique products startups generate new needs. These new needs translate into valuable new design requirements for ink manufacturers. Startups can then provide feedback to ink manufacturers to improve their inks, processes, and capabilities.

4.3.2 Academics

Academic researchers’ work on state-of-the-art technology is an essential long-term market driver. Stanford University has several world leading labs. We interviewed the HeyRyoung Lee, a PhD candidate in Department of Material Science at Stanford University. She offered great help on both the need finding process and feedback on prototypes. Results are as follows:

Collaborations are quite beneficial for academic researchers. Like startups, doing research requires a wide range of technology, resources, and materials. Searching for information and materials by contacting corporations is time consuming and sometimes not quite efficient due to the disorganized status of the industry. They need a community or a market-place to share ideas and where people, technologies, facilities, and materials are accessible to people in the industry.

Printed electronics conferences are key events because these are where they can meet people with new ideas. Attendees at the conference are always attracted to tangible showcase demos and beautiful presenters. This is a good way for startups and academics to show their achievements to get attention. Potential partnerships can be generated from these conferences.

Face-to-face communications are important for exchanging information and getting new ideas. International conferences maybe a good place to start, but not enough for researchers
to solve their daily challenges. They need a community that can get faster responses from other people who have the expertise to solve their problems and correspondingly resources.

4.3.3 Clariant itself
Printed Electronics is a new business unit for Clariant, but they are not new to the industry. Clariant has years of experience producing inks for commercial printers. Both traditional commercial inks and printed electronics inks share some of market intelligence and the key players are similar in both (especially printing companies). They also have many similarities with respect to materials processing knowledge such as reliability and feasibility estimation. Clariant could leverage these competences derived from other successful business units to facilitate startups by accelerating their design process.

Clariant will enter the printed electronics industry as an ink seller. Through building an open and trustful community with Clariant’s potential customers and collaborators, startups and academics, they are able to acquire innovations. New design requirements raised by startups are valuable to Clariant’s R&D for new products, and academics state-of-art technology will keep them running as leaders in the cutting edge of industry.

4.4 Vision Development

4.4.1 Benchmarking Innovation

Last quarter’s conclusion
At the end of the fall quarter, we had identified a galaxy of potential innovators for our platform in what we called the innovators cosmos.

![Figure 18: The Innovators Cosmos](image)

We came up with the augmented fume hood, an environment for remote collaboration between the innovators and Clariant, to be implemented in any lab or office space willing to collaborate with Clariant as well as in Clariant’s own innovation R&D centers. It enables flawless communication between potential partners as well as information sharing about experimental procedures or products information.
As we entered winter quarter we decided to further develop the tools that allowed better and faster prototyping. The choice to focus in printed electronics in late January alleviated our duty, and allowed us to have better focus on a specific set of tools, for both printed electronics materials prototyping and application testing.

### 4.4.2 Exploring the existing tools for quick hardware prototyping innovation

**Hackerspaces and FabLab**

When looking at Silicon Valley’s environment, we saw that there were numerous prototyping spaces and Tech-Shops that were accessible on a subscription or pay per use basis.

![Tech Shop logo](image)

Even at Stanford, places like the PRL or the TLT lab offer opportunities for anyone with an idea to go and prototype it there.

![Stanford Product Realization Lab](image)
Tools
Places like the PRL or Techshop offer a wide range of prototyping tool from rotary tools to woodworking or smithing tools. But we see more and more computer controlled tools appearing in those semi-industrial environments, like CNC, laser cutters or 3D printers. The two latter tools allow a user with limited manufacturing experience to produce in a very short time a complete mechanical prototype.

We found that some chemicals industries were already asking for these kinds of tools. For example, the dye and pigment industry is now able to quickly prototype a new color with tools like the Robolab [Robolab] that stores standardized colors and mixes them together with a control system to ensure a precise process.
Tools in the printed electronics industry
We learned from our interviews that fast prototyping indeed exists in the printed electronics lab. It appears that people using inkjet-printed electronics were in fact using printers that were either very close to or identical to actual inkjet printers commercially available. An industrial inkjet printer for printed electronics prototyping is shown in Figure 24.
Melbs leMieux from C3 Nano hinted to us that regular desktop inkjet printers were used to do fast prototyping.

4.4.3 Benchmarking the Start-Up innovation process

We needed to articulate any ideas we had to the current start-up idea developers. As a result we became interested in the initiatives that were at the origin or that helped start-ups and products to grow from an idea.

Accelerators/incubators

One of the most prominent initiatives at Stanford promoting entrepreneurial spirit among students and professors is StartX, Stanford’s start-up accelerator. We were surprised to see that StartX is a non-profit; they take no equity from the start-ups that are incubated, but offer them office space and resources, and in fact they give way more than that.

We had the chance to meet three StartX associates: Andrew Scheuerman, Tony Lai, and John Melas-Kyriazi, and talk to them about their methods and philosophy. StartX is a community of entrepreneurs and innovators that share the same life experience of building a start-up over a span of 3 months. That is really what StartX provides. Mentorship by alumni or partners is also a part of the community building. We also found out that incubators have close partnerships with VCs or big companies like Microsoft that have managed to penetrate these small trustful circles with various means. For instance, Microsoft used a disinterested approach by providing free development platforms for the developers at StartX. The approach was also made under a neutral name, the Bing Fund, lead by a hero of the hacker
community to give him the necessary amount of legitimacy in the community and this technique worked very well.

Start-up week ends
During the course of the quarter, a start-up week-end was organized at Stanford by StartX. This event, which happened during the course of a weekend, gathered a group of approximately a hundred people willing to work 50 hours straight to get a first draft of a prototype and a business plan for a start-up.

Alexandre took part at that event and found several key findings from this experience:

- A sort of pre-pitch phase of the different projects happened on the event LinkedIn and Facebook pages a few day before the event, with each participant describing his profile, his idea, and what he could offer to a potential team, but most importantly what kind of competence he needed.
- The face to face interaction happening at the event allowed a deep level of connection between the participants. Many teams formed during the event felt very involved and kept on meeting after the event.
- The StartX team setting transformed the interaction beyond the level of the professional encounter. Organizing breakout sessions with food and a giant rock paper scissor game with the 100 participants helped this transformation.

4.4.4 Initial vision
Enhancing collaboration
We had from the start of the quarter two interesting paths for the future of the project. The first one being a focus on the prototyping technologies in order to enhance collaboration, the other was linked to all the aspects of building and consolidating a community. At that point many ideas started to emerge, seeing the limits of remote collaboration, and shifting to more face to face interaction during events and places dedicated to chemical innovation.

One idea worth mentioning is the Iron Chemist Challenge, maybe our first try at imagining the format of an event that would bring innovators to compete and participate to a Clariant program.
The printed electronic shift
At the end of January, it was decided to give the project a more precise direction with the focus in printed electronics. It very positively influenced the development of the project, helping us to concretely visualize the tools needed for innovating in the prototyping field. As cutting edge technology printed electronics has many aspects and angles for us to start thinking about the innovation problem. It also gives the possibility to use this technology as a potential technologic showcase for Clariant know-how and products. The other interesting aspect being the fact that Printed Electronics is still in the process of being launched at Clariant, this business unit could still be qualified of a “start-up” within Clariant.

4.4.5 Prototyping the collaboration machine environment

The threefold vision idea

![Figure 28: Initial threefold vision](image)

Our idea to get the best of the need finding and benchmarking we had done so far was to divide our vision in three different parts and start defining more precisely each of them. In
this threefold vision, we see first the web-platform, a virtual backbone for the community, and then showcase events that are incorporated as a possibility for Clariant to attract new innovators while demonstrating its capacity to come up with innovative technology. The social meet-ups are events for bringing the community all-together to innovate.

**Website**

The website is a central hub for the Clariant community. It enables asynchronous online connection and communication between the members of the community. It also serves as a database of members of the whole community. The prototype of the website was developed at St. Gallen.

![Website prototype homepage](image)

**Figure 29: Website prototype homepage**

Trying to fulfill the need for specific resources that some innovators would need but that could be provided by other innovators, we thought of the website as a hub of supply and demand in the printed electronics industry for members of the community that are then able to find the members of the community capable of helping them.
After the initial configuration, a matching algorithm finds the right innovators based on your needs, skills, and resources. Clariant employees would be incorporated in the searches. Our research proves that people are willing to incorporate Clariant employees in their connections. We think it is a great opportunity for Clariant to start to communicate directly with the members of the platform. Clariant is not only a community manager but also an active member of the community.

**Figure 30:** Configuring a search asking for specific resources.

Beyond traditional events

The events goal is to get the face to face interactions started and start to build a sense of community. The social meet-ups especially allow the members of the community to get together in a unique environment different from their corporate office or lab. Those are occasions of forming real relationships or sparking new ideas. The Start-Up week end or
Innovation Challenge format seem very adapted in this situation. But in an effort to get those events to stand out, we want to leverage the prototyping potential of printed electronics to make them unique to Clariant’s PE innovation. This is how we decided to incorporate our collaboration machine that would eventually become the 3d surface printer.

**The collaboration machine**

The idea behind the collaboration machine is to be, on the one hand, a showcase device for Clariant printed electronics innovation but also to be a collaboration platform during the face to face interaction phases. It has to fulfill in short the following requirements:

- Usefulness and collaboration
- Portable
- Making the platform unique
- Cutting edge technology taking advantage of the properties of printed electronics
  - Flexibility
  - Very low thickness
  - Cheap mass-manufacturing
  - Easily adaptable to the sub

### 4.5 **Prototyping the vision**

#### 4.5.1 **The Hackerspace**

The Printed Electronics technology enables flexible and thin circuits design, as well as cheap and mass production. Thus it is desirable for the prototype to utilize the advantages of Printed Electronics and provide the target users with a new user experience without compromising utility. After benchmarking several shops and fab labs, the team realized that a hackerspace environment could help target users to expand their imagination and come up with really
innovative ideas. In this round of prototyping, the goal was to check how the Printed Electronics technology in a hackerspace could facilitate idea generation. The schematic of the fab lab is shown in Figure 33.

In the future, 3D printers that can print electronics will become a reality, but they are still in the development stages. It is not an immediate possibility to incorporate them into maker spaces and fab labs. However, this possibility has a huge potential to revolutionize prototyping, and therefore the innovation process, and at the same time put Clariant in the center of it. The combination of a nascent technology and this huge potential make this platform suitable for idea generation and sharing.

The team set up a fab lab environment with an incredible (but fake) 3D printer that can print electronic circuits and components directly into or onto mechanical components. However, instead of using a real 3D circuit printer, the team asked test subjects to do the job of the 3D printer by hand (and thereby design a new product) by putting paper cutouts of different components on objects in the lab space. Then the team watched and recorded the whole process of how they could unleash their creativity and if they could come up with “wow” solutions using simulated rapid prototyping.

**User Testing and Results**

While we were making the prototype, we interviewed Professor Ohline, who is responsible for selecting equipment for Room 36, which is one of the largest fab labs at Stanford. He was not aware that 2D or 3D electronics printing technology existed, but was really excited by the idea. Our 3D printer idea seemed to fit perfectly in a fab lab or maker space environment. After this, we tested our prototype with ten ME310 classmates as shown in Figure 34. Each test consisted of two phases:

1. Education: The team provided the test subjects with background information of Printed Electronics and the testing scenario.
2. Prototyping: Given the paper cutouts of a large variety of components, the test subjects were asked to pick up any 3D object and use tape to stick the paper components to the 3D object to augment the functions of the object. The subjects enjoyed the process of simulating the use of the 3D printer and using their imaginations to come up with new products.
Findings

- People had a great time imagining product ideas using our system. Being able to rapid prototype their ideas really unleashed the creativity of some test subjects. One of the test users invented an augmented tennis racket that has a camera system and a force feedback sensor. Another typical invention is an augmented ruler with batteries, LCD screens, and temperature sensors. It can be seen that a large number of new applications of Printed Electronics were exploited with the help of fab lab and the fake 3D printer, which contribute tremendously in idea generation and sharing.

- Mocking up the actual electronic components on our devices (simulating rapid prototyping) encouraged subjects to think through and flesh out the functions of the object/system. Given the paper component, the subjects reflected that they thought more about the requirements of the 3D object; i.e. how they can improve the functions of the object, which turned out to be really useful for idea generation and sharing.
• People with the most developed “prototyping mindset” appeared to be very interested based on the survey results. For the 10 test subjects, the average level of being interested is 7.38 out of 10. However, the variety of available components confused some test subjects, who appeared to be the ones that had the most limited technical background.

• When asked about the cost of such a system, it appeared that people were expecting to pay about the same price as an advanced 3D printed (under $20,000). The actual price of a 2D ink-jet electronic printer is of about $40,000. We imagined a subscription model to have access to such a device and people were about to pay a median value of about $20 per month. This is more than the price of access to a fab lab such as room 36. The cost of access to printing materials still needs to be discussed.

• The paper icon-based user interface also raised two major questions: should the process be more guided or constrained? How much of the actual engineering should appear in the user interface? Even though the prototype was mostly tested on engineering students, they were not very familiar with printed and organics electronics technology. The team hypothesize that it is more desirable for Clariant to focus on users from universities and start-ups instead of end product consumers who are not as familiar with the technology. Thus the team decided to narrow down the target user and prototype scope to be more Printed Electronics or application design engineering oriented.

4.5.2 The Patchduino

Patchduino is “Patch” + “Arduino.” It is a collaboration machine prototype that puts electronic circuit components into a sticker format and allows users to stick the components to the surface of a 3D object to make thin, flexible, and compliant circuits. The team envisioned that in the future real Printed Electronic sticker components could be manufactured and implemented in circuit design and prototyping to replace discrete components (imagine rows of drawers with stray components replaced by an orderly book of stickers!), but currently the team simulated the stickers with surface mount sandwiched between two stickers. The materials for making the stickers are the circuit components, conductive bare inks, copper tape, stickers, and basic 3D objects. Each sticker has three layers: the base sticker, the component soldered on copper tape, and a label sticker, as shown in Figure 35. In order to simulate the PE stickers, the chosen electrical components are very small so that they can fit into the space between the two sticker layers. General information about the component is provided on the label sticker so that users can use the components in a familiar way.

Figure 35: Sticker layer sketch.
Sticker Advantages

Rapid Prototyping:
- The stickers have printed symbols and specs, along with flat sheet form factor that allows for easy storage and sorting in a booklet instead of stray components and wires in a box, which can be easily lost or disorganized.
- Stickers can be peeled and applied, and conductive ink and copper tapes can be used to draw connections. This is faster than wiring conventional components on a breadboard.
- Circuits design and prototyping on 3D surfaces can be done by sticking and drawing, which is very difficult for conventional components.
- The sticker format can eliminate wire connections which can catch, come loose, or crowd an assembly.

Flexibility:
- Stickers can be applied to curved surfaces; i.e., putting electronics where they could never be before.
- Stickers can be folded into shapes.
- The sticker form factor minimizes clutter vs. circuits with wires and discrete components.

User Testing

After tens of electrical stickers were fabricated, we provided test subjects with Bare conductive inks and copper tape to connect the stickers to make a whole electrical circuit. The sticker form can give the subjects a lot of freedom and imagination space to come up with new circuit design integrated with 3D physical objects. Subjects usually did not need breadboard and jumper wires, which would consume a lot more space and look more awkward. Instead, they could simply stick the components to the mechanical parts and make them as a whole body. Even though the prototype stickers were low resolution and poor performance, it still gave test subjects and the team some vision and inspiration of what this can look like if real printed electronic stickers are used.

The team simulated the printed electronics conference environment by engaging users, educating them about the showcase product, and then having them brainstorm and prototype using the showcase product. The user testing scenario, shown in Figure 36, consisted of three phases:

1. Education: The team introduced the sticker idea for prototyping and gave them some printed electronics background information.
2. Brainstorming: The team provided the test subjects with stickers of various components, and helped them to explore their ideas for applications.
3. Prototype: Test subjects were instructed to design a LED flashlight on a curved surface.
The test subjects were given a Patchduino sticker/pen prototyping kit, shown in Figure 37, which contained the following materials:

- Resistors Stickers
- LED Stickers
- Capacitor Stickers
- Touch sensor
- Conductive ink (Bare)
- Flexible solar cell

The typical flexible circuits that the test users made are shown in Figure 38 and 39.
Findings

Attractiveness:

- The test subjects reflected that circuit components in a sticker format are “really cool,” but while the current stickers might be suitable for high school education and university mechatronic rapid prototyping, they might be less attractive for printed electronics field experts. University researchers and startups are already familiar with the technology and may be more interested in a prototyping tool that can help them further develop new products directly from inks. Stickers are more oriented to designers outside the printed electronics community.

- One of the test subjects pointed out that medical devices might be a potential application field for printed electronics stickers because the medical community is especially interested in flexible electronics.

- Some test subjects recommended different sets of discrete components or modular components for users with different levels of electronics expertise. For users who are new to electronic circuit design or need highly customized circuits, discrete components can help them better understand the theorems and precisely control the circuit. However, for electronic experts or people that don’t need a lot of customization, prototyping with discrete components is a waste of time, and modular components could save time, are more robust due to the encapsulation, and eliminate the need for detailed circuit design expertise.

Figure 38: Flexible circuits designed by test subjects. The left is a wearable device to light up an LED; the right is a cluster of LEDs lit up by an Arduino

Figure 39: Flexible circuits designed by test subjects. The left is an augmented hammer with buzzers; the right is sticking LEDs and copper tapes on a curved container.
• Not only should the stickers be oriented to different target user groups, the corresponding web communities could also have different sections for different user groups, such as printed electronics people, kids, doctors, etc.

Usefulness:
• The stickers are useful in theory, especially for users outside the printed electronics industry, but the execution had some problems. Because the stickers were simulated with regular stickers and regular components, the connections were not robust enough for handling/flexing. Slow drying Bare paint was terrible for fast prototyping because of its high resistance. The debugging process was especially difficult, and hiding the components between the two sticker layers created additional difficulty.
• Mechatronic students reflected that it was fun to prototype using our sticker tools. And after getting familiar with the sticker components, one tended to spend less time on prototyping the same circuit than conventional components.
• The capability to prototype on 3D surfaces was well received. Almost 70% of the test subjects indicated that they would definitely use this tool for mechatronics prototyping, if the robustness is guaranteed.
• The test subjects also said that there are not enough different components for a wide variety of circuit design. And the components were also perceived as too big.

4.5.3 3D Surface Printer

Vision
The team wanted to show Clariant how to build a printed electronics community. The community will include all talents in the industry: startups (inks and applications), academic researchers, and Clariant expertise. The most valuable commodities this community will provide are high quality, long lasting collaborations. This is the “open innovation” aspect of the community. However, by bringing together companies and academics from all parts of industry, the community will also provide quick access to different sources of materials, facilities, and expertise. Clariant, a cofounder of this community, will use it to form its own collaborations, with the added incentive of its ability to provide valuable market intelligence and business knowhow.

The 3D surface printer is a shiny new technology, accessible and inspiring for people even outside the Printed Electronics industry like artists, engineers, and fashion designers. It not only draws people in with its “shininess,” it also serves as a platform on which they can practice collaboration by prototyping new ideas. It also leverages Clariant’s existing partnerships with printing companies to gain credibility in a new industry and show that Clariant is well connected.

By facilitating communication and collaborations among diverse people and resources, the entire industry will benefit and grow, and Clariant will be able to produce the most cutting edge inks, sell them to the start-ups for them to prototype and become good suppliers for large scale manufacturing.

Printed Electronics is analogous with 3D printer industry. RepRap, an open-source 3D printing system and collaboration community, kick started the widespread use of 3D printers
in 2005. Then Shapeways launched a private beta for a new co-creation service and community, allowing artists, architects, and designers to make their 3D designs as physical objects inexpensively in 2008. Emerging medical applications that used 3D printing drew public attention and further accelerated the development of 3D printing technology. 3D printers are now commercially available for home desk use. By applying this historical roadmap, the printed electronics industry needs an open innovation community and easily accessible prototyping tools. The Printed Electronics industry is growing too slowly for such a cool technology. Thus the team believes that an innovative application from collaboration by artists, doctors and Printed Electronics experts will bring a revolution to the industry.

With the lessons learnt from the previous two prototypes, the team came up with the 3D surface printer design to make the collaboration machine truly useful and attractive. The 3D surface printer, shown in Figure 40, was modified based on the frame and actuation system of a Canon inkjet printer. The motors actuated the motion of printhead and the feeding of the 3D object, which in this case is a cylinder. All the motions and printing process are controlled by an Arduino UNO with an H-bridge board and an InkShield board. In order to verify the ability of printing conductive ink on a 3D geometry efficiently, the team filled the regular cartridge with conductive ink and printed zigzag and hysteresis curves on a cylinder, which is used to simulate future electronic patterns.

![Figure 40: 3D surface printer prototype.](image)

**Technical Testing**

The team first tested the printhead by printing regular inks independently from the frame, printing object and actuation system. The characters printed were encoded inside the Arduino Integrated Development Environment (IDE) with the Inkshield library from the Arduino online community. As shown in Figure 41, the printhead was able to print the characters on a human body by moving the printhead by hand.
After verifying the ability to print regular inks on flat surface (human body), the team integrated the system by both controlling the motion and the printhead. By moving the printhead back and forth and rotating the cylindrical object, and at the same time actuating the printhead (printing ink), the team was able to print characters on the surface of the cylinder, which is shown in Figure 42.

However, the printing process is still done line by line. For real electronics patterns, the shape could be highly irregular and thus this printing method is not suitable. A better way for printing curves is to print along the pattern contour by making the printhead traverse along a predefined trajectory. This requires coordination among the two motors and the printhead. The team defined two patterns for trajectory traversing testing: a zigzag pattern and hysteresis pattern, which are shown in Figure 43, 44 and 45.
Figure 43: Controlling regular printhead to print zigzag patterns on 3D object

Figure 44: Controlling regular printhead to print hysteresis patterns on 3D object

Figure 45: The expanded view of the printed patterns
Technical Findings

- The distance between the printhead and the surface of the 3D object is a critical factor for the performance of the final pattern and circuit. Large distance will lead to poor printing results.
- Inertia of the 3D object has a large effect on the precision of the printing pattern. Heavy 3D objects with large inertias often bring too much load on the actuation system. Thus it takes more time for acceleration and deceleration. A good way to solve this problem is using gear reduction.
- Open loop control is not accurate and always has disturbances that cannot be eliminated. Closed loop control with position and velocity feedback could help improve this. A typical closed loop precise control for motors is Proportional-Integral-Derivative (PID) control.
- Conductive ink dries very quickly inside the cartridge nozzles, so it needs to be washed with ethanol every time before printing, otherwise the printhead could be stuck with dried inks. It would be more desirable if there are washing/cleaning systems similar to regular printers.
- There are two ways to print on a 3D surface geometry. One way is using a large matrix storing the whole image of the pattern and printing one row after another by traversing every row. The requirement for this method is that the inertia could not be too big because the distance between each row is small. The other way is to print along the pattern contour by making the printhead traverse along the predefined trajectory. This method requires precise control of motors for trajectory tracking.

User Testing and Findings

The team conducted an online survey with the ME310 design student community, printed electronics startups, and university researchers: 30 test users in total. The team first introduced the whole system of the innovation platform, providing some background information of the showcase event, social meet-up event, and web-community. Then the team showed the test subjects a video of the surface printer printing characters and complex patterns, and then asked them whether they are interested in participating in the showcase event, web-community, and using this device for rapid prototyping. Part of the survey result and findings are shown in Figure 46 and 47.

As indicated in the result, 63% percent of the subjects were interested in using the surface printer for rapid prototyping after watching the video of the printer working. 37% of the test subjects showed neutral for using the printer. None of the subjects showed that they not interested in this, which is really desirable for this prototype. For the collaboration aspect of this surface printer, 20% of the test subjects showed interested, yet more than 70% of the subjects showed neutral or not interested. In contrast with the first graph, the team attributed the tremendous drop in the number of interested people to the procedure of filling in profiles and providing background information. The rest of the survey result is in Appendix.
Figure 46: User testing of the Surface Printer

Figure 47: User testing of the Surface Printer
5 Design Description

5.1 3D Surface Printer Prototype

5.1.1 Functional and Physical Specs
As mentioned in the Design Development section, the 3D surface printer consists of five parts: 1) the frame, 2) the printhead, 3) the printing object, 4) the actuation system, and 5) the controller. The frame was made with laser-cut Masonite board. The frame was attached to the fixed support with screws, and the support was reinforced with ribs, which is shown in Figure 48. The printhead is a normal inkjet cartridge, known as the HP Generic Reduced Height Blue Ink Cartridge, which is shown in Figure 49. The cartridge was connected to the Inkshield actuating board controlled by an Arduino UNO microcontroller using parallel buses, and the motor was actuated with an H-Bridge board, which is shown in Figure 50. The code for controlling the inkjet printing process was developed in the Integrated Development Environment (IDE) of Arduino with the help of an open source library compatible with the Inkshield board. For printing characters, the printhead was actuated to move back and forth for printing one line of words, and after finishing each line the cylinder was rotated to get ready for another line of printing. The characters were encoded in the program with the help of the library mentioned above. For printing zigzag patterns, the printhead and the cylinder moved one after another to generate a zigzag pattern, and the cartridge was coded to always ejecting ink. For printing more complex patterns such as a circle, the motions of printhead and the cylinder were coupled, making the control scheme more complicated.

Figure 48: The fixed support structure reinforced by ribs
5.1.2 Requirement Fulfillment for the Collaboration Machine

Table 7 maps the 3D surface printer prototype to our design requirements for the collaboration machine.

<table>
<thead>
<tr>
<th>Design Requirement Recalling</th>
<th>Fulfillment</th>
</tr>
</thead>
<tbody>
<tr>
<td>The printer should be useful, especially for Printed Electronics people.</td>
<td>Really suitable for rapid prototyping; especially useful for the printed electronics field.</td>
</tr>
<tr>
<td>The printer should promote collaborations between people.</td>
<td>This should come together with the whole system, which has not been tested yet.</td>
</tr>
<tr>
<td>The printer should make the system unique.</td>
<td>This is the first 3D surface printer for Printed Electronics in the world, which is really unique.</td>
</tr>
<tr>
<td>The printer should show the cutting edge technology of Printed Electronics.</td>
<td>The flexibility, thinness, and cheap mass production are all shown with the printer.</td>
</tr>
<tr>
<td>The printer should be attractive.</td>
<td>According to the online survey, people were really interested in this printer.</td>
</tr>
<tr>
<td>The printer should be portable.</td>
<td>Currently the printer is within 2kg.</td>
</tr>
<tr>
<td>The printer should be able to print</td>
<td>The team is still working on this function.</td>
</tr>
<tr>
<td>Conductive ink on different substrates.</td>
<td>The printer should have a good implementation of control algorithm.</td>
</tr>
<tr>
<td>----------------------------------------</td>
<td>-------------------------------------------------</td>
</tr>
<tr>
<td>The printer should have a proper distance between the printhead and the printing object.</td>
<td>The team is still working on this function.</td>
</tr>
<tr>
<td>The printer should have a good ability to move and rotate the 3D object with different inertia.</td>
<td>The distance for the current printer is proper enough for regular ink and conductive ink.</td>
</tr>
<tr>
<td>There should be cleaning/washing system to avoid the cartridge getting stuck.</td>
<td>The current printer is not doing this well. There is still some hysteresis caused by the large inertia comparing to the actuating ability of the motors.</td>
</tr>
<tr>
<td>Currently the process is done by hand.</td>
<td></td>
</tr>
</tbody>
</table>

5.2 The project configurator

1.1 Physical Specs
The website was made at the University of St. Gallen using the Axure Platform, a tool for fast prototyping of website layout and basic interaction. It consists of a several pages with interactive pre generated contents and links to YouTube videos for some user profiles.

1.2 Structure

Figure 51: Configurator homepage
On the actual homepage people can play on each of the pieces of the puzzle to specify what they need or can provide in terms of expertise, materials, facilities or devices.

A pre-selection of the items to be displayed in each section and is to be refined as the community is growing. Clickable boxes and text fields were incorporated. Once completed the “Configure my project now!” links to the next page.

The matching page presents to the user short profiles of potential innovators that corresponds to their “supply and demand” criteria. Among those, we find Clariant employees that are clearly identified in the list.
Eventually the profile page details each member’s info’s (position, Expertise fields, Academic Background, Hobbies, link to other networking platforms) as well as a collaboration score. The members can then enter in contact through the “Ask”, “Collaborate”, or the “Apply for Mentorship” button.

Figure 54: Sample profile page
6 Project Planning

6.1 Extended Team Description

Figure 55 Our project’s stakeholders

6.2 Communication Protocols

Videoconferencing:
Currently used:
Google Hangouts - Web Based Video Conferencing Solution
Pros:
- Large number of users possible during one conversation
- Intelligent detection of the user speaking
- Web based
- Screen Sharing possibility

Cons:
- Hosted by Google

Global Line + Lync for Screen Sharing
Pros:
- Large number of users possible during one conversation
- Available through any phone
- Screen Sharing

Cons:
- Poor quality of the line in areas with a poor service
- Uncontrollable echo
- Hard to identify the speaker

Other available solutions:
- Skype based solution at the University of St. Gallen.
- Two Polycom Units available at Stanford - Polycom compatible open-source windows software exist but have to be tested.
- Polycom seems to be the preferred solution and is the most adapted in a business environment. Potential Polycom Unit at St. Gallen, has to be confirmed.

File Sharing
Dropbox:
Two main file sharing folders:
Stanford/St Gallen “Back Office” folder: 3.3 Go of data at the moment, used as a tool during the design thinking process.
Clariant/Stanford/St Gallen “Front Office” folder: Will contain synthetic documents summing up the findings of the design thinking process. (In progress)
Permission can be requested to have access to both folders.
Access at the Dropbox possible via the Dropbox website (account registration is necessary) or through a Windows App that shares one folder on your computer.
Link redirection to the files on websites and documents is also possible.

Email lists:
- Stanford team members: 310-clariant-su@lists.stanford.edu
- HSG team members: 310-clariant-usg@lists.stanford.edu
- Both Stanford and HSG team members: 310-clariant-global@lists.stanford.edu

Website
The Posterous website is made to provide a complete overview of the team’s progress with all meeting minutes, literature review and findings made by both Stanford and St Gallen. Posting, editing and commenting is only available only for registered users, but viewing does not require registration.

chemicalsbetweenus.posterous.com : Public Website
chemicalsbetweenusinprivate.posterous.com: Private Website (password: sunflower)

This website will be shut down in April as Posterous was acquired. We will transfer our website to another service.
6.3 Overview of Winter Quarter Activities

Three major prototypes have been done this quarter, within the range of 8 weeks, as shown in Figure 56.

Gantt Diagram

Figure 56: Gantt chart for activities in Stanford team
6.4 Winter Activity Details

January 17th: Dark Horse Challenge

The Stanford team started to intensively work on the Clariant project this quarter starting January 17th with the launch of first prototype challenge: the two week Dark horse challenge.

In the first week from Jan17th to Jan 23th the team explored innovation opportunities for Clariant’s traditional business units as in fall quarter. As of the release of a new design brief on Jan. 21th, the project shifted to Printed Electronics, a new business unit Clariant had just developed.

Since the whole project launched in fall quarter, the team went through the benchmarking and need finding procedures, and winter quarter was designated to build the vision based on these findings. Though traditional chemical units from Clariant are different from printed electronics, both the Stanford team and St. Gallen team were able to quickly iterate the design thinking process for benchmarking and need finding right after the new design brief released.

The St. Gallen team visited Stanford at the end of January. Physically working together as a whole team benefited both the people and project. Engineering students and business students were able to leverage each other’s expertise and advantages. This global trip made for a good kick start to the project.

February: Funk prototype and Functional prototype

Since the project shifted to printed electronics, the following three weeks the team needed to design and prototype at the same time along with benchmarking and need finding.

February was when most of this work was done. The team was able to connect with resources at Stanford, such as knowledgeable academic researchers from two famous labs in the field of Printed Electronics. Several interviews with them accelerated the whole benchmarking process.

With special thanks to HyeRyoung Lee, a kind and open-minded PhD candidate, the Stanford team was able to identify needs for one of the target users as academic researchers.

Another helpful trip to StartX, an accelerator in the Stanford community, gave us good knowledge about the startups’ point of view on innovations and collaborations, especially to observe the relationships between big corporations and small startups. Future possible partnerships between Clariant and StartX will be discussed next quarter.

Due to effective brainstorming during the two teams meet in Stanford, the final system level design was agreed on by both teams.

For the funky prototype and the functional prototype, the Stanford team worked on tangible showcase part of the whole system, and the St. Gallen team worked on the web platform. Through weekly global video calls and timely updates through emails and Posterous, the two
teams were able to work closely as the whole team to prototype. Also, biweekly phone calls with Clariant’s liaison, Dr. Tobias Macholdt, generated comments and advice that gave both teams feedback and insight.

March-Functional prototype and final documents, and global travel
The Stanford team interviewed Melbs LeMieux, the co-founder of C3nano, a startup that produces conductive ink. They also interviewed Dave Eagleson, the VP of sales for Solicore, a startup that produces flexion batteries, which helped them to understand startup needs better. The final vision design was also refined.

In March, the functional prototype of 3D surface was improved each week. Most of the budget was spent on conductive inks and printer cartridges.

On March 21st to March 28th the Stanford team will travel to St. Gallen to work with the St. Gallen team. The Stanford team will have a chance to visit Clariant to establish closer contact. By observing Clariant’s innovation center and talking with the employees, the team is expected to get valuable feedback for the prototypes.

Finally, with the results from the three prototypes, from Stanford side, what can be done in spring quarter to finalize this solution to Clariant’s innovation challenge can be predicted.

6.5 Budget report and planning

This section covers the money spent with the Stanford team on this project. For the winter quarter, there were $3,000 dollars allotted plus $767 rolled over from fall quarter for the Clariant project, total $3,767. By the end of this quarter, Stanford used $708, and the remaining $3,059 in funds will roll over to the next quarter.

Stanford Budget
Most of the budget this quarter was spent on buying printed electronics products, from conductive pens, to conductive inks. A small portion of the budget was spent on the prototypes before the design brief shifted to Printed Electronics, such as chemical glassware and equipment. Generally, the team is able to spend the money efficiently and smartly. In general, the team spent less than the budget allotted for this quarter. And money rolled over to sprinter quarter is expected to meet the need for developing the final prototypes.
### 6.6 Winter Quarter Expense Report

#### Table 8: Winter quarter expenses

<table>
<thead>
<tr>
<th>No</th>
<th>Date</th>
<th>Vendor Name</th>
<th>Description of Expense</th>
<th>Pre-tax Amount</th>
<th>Shipping</th>
<th>Amount Incl Sales Tax</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1/14/2013</td>
<td>PRL LAB</td>
<td>Who: Dan&lt;br&gt;What: Electronic Components&lt;br&gt;Why: Paper Robot prototype</td>
<td>$20.30</td>
<td></td>
<td>$20.30</td>
</tr>
<tr>
<td>2</td>
<td>1/16/2013</td>
<td>PRLLAB</td>
<td>Who: Alex&lt;br&gt;What: Electronic Components&lt;br&gt;Why: Paper Robot prototype</td>
<td>$27.00</td>
<td></td>
<td>$27.00</td>
</tr>
<tr>
<td>3</td>
<td>2/6/2013</td>
<td>Fry's</td>
<td>Who: Alex&lt;br&gt;What: Electronic Components&lt;br&gt;Why: Funky prototype</td>
<td>$44.98</td>
<td></td>
<td>$48.86</td>
</tr>
<tr>
<td>5</td>
<td>1/25/2013</td>
<td>San Jose Scientific</td>
<td>Who: Scarlett&lt;br&gt;What: Chemicals, glassware&lt;br&gt;Why: Darkhorse prototype</td>
<td>$118.55</td>
<td></td>
<td>$128.77</td>
</tr>
<tr>
<td>6</td>
<td>1/18/2013</td>
<td>Amazon</td>
<td>Who: Alex&lt;br&gt;What: OWI Robot arms&lt;br&gt;Why: Dark horse prototype</td>
<td>$45.05</td>
<td></td>
<td>$48.94</td>
</tr>
<tr>
<td></td>
<td>Date</td>
<td>Vendor</td>
<td>Who</td>
<td>What</td>
<td>Why</td>
<td>Item 1</td>
</tr>
<tr>
<td>---</td>
<td>------------</td>
<td>---------------</td>
<td>------------------------------</td>
<td>-----------------------------------</td>
<td>----------------------------</td>
<td>--------------</td>
</tr>
<tr>
<td>8</td>
<td>2/13/2013</td>
<td>PRL</td>
<td>Scarlett</td>
<td>2 sensors</td>
<td>Funk prototype</td>
<td>$14.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>2/14/2013</td>
<td>Tresidder Express</td>
<td>Alex out of pocket</td>
<td>Spoons and forks</td>
<td>SUDS</td>
<td>$14.50</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>2/25/2013</td>
<td>Printer</td>
<td>Dan by out of pocket</td>
<td>Printer-used</td>
<td></td>
<td>$15.00</td>
</tr>
</tbody>
</table>
6.7 *Expectations for spring quarter*

The 3D surface printer will be our final prototype. As part of the whole system, working with St. Gallen prototypes, the 3D surface printer will be able to add degrees of freedom to be able to print on more complex objects. A brief list of next steps:

- 3D surface
- 6 Degree-Of-Freedom robotic arm
- Conductive inks
- Really printed electronic circuits
  This design will be finalized by Stanford team, and part of the execution will be achieved by hiring someone with expertise to do interface design, etc. More budget will be allocated here for buying printer development materials and human sources.

During the spring quarter, more prototype development will require some purchases, and also some part of the design may require us to hire some additional expertise. The following is the spring budget planning based on the current project planning. For the spring quarter, $4,000 is allocated to the Stanford team with the $3059.29 left from fall and winter quarter, so total of $7059.29 budget will be available.

Table 9: Spring quarter budget

<table>
<thead>
<tr>
<th>No</th>
<th>Expense</th>
<th>Description</th>
<th>Pre-tax Amount</th>
<th>Shipping &amp; Handling (if any)</th>
<th>Amount Incl Sales Tax</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Conductive ink</td>
<td>100ml 150</td>
<td>$1,000</td>
<td></td>
<td>$1100</td>
</tr>
<tr>
<td>2</td>
<td>Print head</td>
<td></td>
<td>$200</td>
<td></td>
<td>$220</td>
</tr>
<tr>
<td>3</td>
<td>Human resource</td>
<td>User Interface</td>
<td>$3,000</td>
<td></td>
<td>$4,000</td>
</tr>
<tr>
<td>4</td>
<td>Motor</td>
<td>Robot Arms</td>
<td>$200</td>
<td></td>
<td>$220</td>
</tr>
<tr>
<td>5</td>
<td>Micro controller</td>
<td>For Printer</td>
<td>$500</td>
<td></td>
<td>$550</td>
</tr>
<tr>
<td>6</td>
<td>Other development materials</td>
<td></td>
<td>$2,000</td>
<td></td>
<td>$2,000</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>$6,990</strong></td>
</tr>
<tr>
<td></td>
<td>Spring Allocation</td>
<td></td>
<td></td>
<td></td>
<td><strong>$4,000</strong></td>
</tr>
<tr>
<td></td>
<td>Roll over from Fall</td>
<td></td>
<td></td>
<td></td>
<td><strong>3059.29</strong></td>
</tr>
<tr>
<td></td>
<td>Available Balance</td>
<td></td>
<td></td>
<td></td>
<td><strong>7059.29</strong></td>
</tr>
</tbody>
</table>

6.8 Process Reflections

**Alexandre’s Reflection**

This quarter was for us a deep dive in ambiguity. The initial pivot, the struggle for finding a vision convincing enough to meet Clariant’s expectations and problem, as well as our natural attraction for tangible products made us go through an intense period of successive iteration, ideation and pivoting. No autopilot for us in the flight simulator. Getting a unified global
vision might have been the biggest issue for us, but I feel confident that our work to frame the problem as much as possible this quarter puts us in an adequate position for the rest of the year. I personally felt that our team made progress on the aspect of the less talking more doing this quarter with the eventual dive in the technical stuff with the printed electronic shift. I feel glad that I can work on this promising technology that could have an impact beyond the scope of a simple student project. The best sign for that is that I would definitely continue to work on it after the end of the year.

Daniel’s Reflection
It has been an exciting quarter. The new prompt allowed us to focus our task and our thinking. It has been really exciting to have the chance to explore a new technology field and to try to figure out where it’s going and how to get it there. We also seemed to coalesce as a team. The team has gotten a lot closer but is still (usually!) able to be very efficient. We are also very excited to visit Switzerland in a couple of days. Their visit in January really helped the team to communicate, and it seems that communication quickly deteriorated afterward. It will be good to reestablish good communication and build a good foundation for the final quarter.

Hao’s Reflection
After a really intense quarter of brainstorming, benchmarking, and prototyping, I feel our team have done a lot and finally found the right track to come up with a functional platform design plan for next quarter. The hands-on paper robot project gave us some warm-up experience on prototyping, which turned out to be really useful for subsequent prototyping. Even though the design abstracted changed dramatically shortly after the paper robot project, our team successfully kept up pace with other teams, with a large amount of work of technological and business benchmarking, which laid the very foundation of afterward brainstorming and prototypes. The whole team came up with several really innovative ideas that they almost current do not exist. Through the whole process, I learnt a lot from every team member. Alex’s crazy but really shiny ideas, Dan’s initiative in documentation and interviews, and Scarlett’s logical coordination; I benefited tremendously from them and had better understanding of design thinking, especially when we began to converge instead of diverge. I’m pretty confident that the whole team could accomplish a lot in the next quarter and finally have a WOW result!

Scarlett’s Reflection
The winter quarter challenge the whole team a lot, but we had great fun. Design brief shifted from conventional chemical business units to Printed Electronics. Even though “dance with ambiguity“ is sort of our design principal, this new focus thrilled us. Since fall quarter, dealing with various business units distracted us, and it was really hard to find a common solution for all of the business units.

Though the focus came a little bit later, but we felt confident and thrilled to catch up with whole schedule. What we have done last quarter was not wasted. No matter what focus we have, the design thinking process and team work stays. And I have to say, the corporation with the global team is challenging for each of ME310 team, but we became closer during the Chinese New Year, we became close friends and formed a great team.
Though communications just through video chats were not quite enough to keep us in the same pace, that what we will accomplish in daily work in the real working environment. So I was happy to meet the problems. Also, comparing to St. Gallen teams, Stanford was geographically not as convenient as them to communicate with Clariant. Try to convince them to trust our ideas aligning with their design requirements is challenging. Again, I felt the same with last quarter, effective communications play an important role in the success of team work. And, this quarter, within the Stanford team, more heated discussions with intensive brainstorms helped the whole team get new ideas. My English improved. And since we assigned parts of presentations to each team member, the preparations for the final documents improved our presentation skills. That’s good.
7 References

7.1 Bibliography

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[3] "Annual Results 2011". BASF.


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   Company.
   Report.pdf


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   report.clariant.com/uploads/tx_szmediacenter/Innovation__Research___Development.p
   df

    Communication

    Pottgen, Consulting Analyst, Chemicals, Materials & Food, Frost & Sullivan


[16] Printed Electronics USA opening keynotes, IDTechEx,


[20] High efficiency, high performance organic semiconductors for organic photovoltaics and organic sensors, Dr. Monica K. Davis, Manager, Business Development Performance Materials Division, EMD Chemicals

[21]Graphene Frontiers, Printed Electronics USA 2012,

[22] Toward Roll-to-roll production of graphene for printed electronics, Byung Hee Hong, Graphene Square Inc& Seoul National Univeristy

8 Appendix A: Chemical Industry Business Benchmarking

8.1 Business Benchmarking

8.1.1 Chemical Industry Overview [2]

Clariant is a chemical company, meaning that it is a company that produces chemicals. Yet there is no unified chemical industry. Input materials, end-products, techniques or customers found in the different chemical companies are numerous. The chemicals industry provides raw material for more than 100,000 products.

We can make a first distinction between specialty chemicals and commodity chemicals. The higher end of the market is formed by the specialty and fine chemicals. More complex to produce, they have a much higher added value. Example of specialty products are electronic chemicals, industrial gases, adhesives and sealants as well as coatings, industrial and institutional cleaning chemicals, and catalysts.

The rest of the market is comprised by basic or commodity chemicals products. Those chemicals are usually sold at a lower price but in high volumes. The best examples in this category are all the derivatives of oil including plastics.

The chemical industry is facing numerous challenges in the upcoming years:

- Rising prices of raw materials and energy

![Figure 57 Market Categories in the chemical industry](source)
- Increased competition for market share
- Increased competition for talented employees
- Overcapacity
- Political changes and new regulations (especially environmental regulations with for example the REACH system in Europe)

Moreover we see the emergence of new markets like China, India or Brazil with a high demand for high end, specialty products due to an increased urbanization and higher standards of living that create needs in industries such as transportation, health, water treatment, energy or even IT.

Those markets also provoked the rise of new companies who cut the prices on lower end commodity products. Another observation is that products that are currently specialty see their productions cycles and their cost of production rapidly decreasing and will eventually become commodity chemicals.

8.1.2 Major Chemical Companies

BASF (Baden Aniline and Soda Factory), founded in the 19th century in Germany, is the world's largest chemical company at the moment. They operate worldwide and sell a broad range of products, both specialty and commodity. Their net sales in 2011 represented about $95 billion. The company spends each year about $2 billion for R&D. [3]

DOW is an American company founded in the late 19th century. Just like BASF they distribute a broad range of chemicals and operate worldwide. Their net sales in 2011 represented $59.9 billion and the R&D expenses are of about $1.3 dollars.[4]
Bayer is a German chemical and pharmaceutical company founded in 1863, the majority of their products are related to HealthCare, but they also sell agriculture related products or products for electronic or automotive industry, they as a result count a lot on their innovation power. Their net sales represent about $46 billion for annual R&D expenditures of $3.6 billion.[5]

Procter and Gamble (P&G) is an American consumer goods company founded in 1837. Their products include cleaning agents, personal care products or pet foods and as a result use technologies from the chemical industry. 26 of P&G’s brands have more than a billion dollars in net annual revenue. Being marketing specialists they are experts on consumer behavioral study, with their $250 million Becket Ridge Innovation Center for example. Their net sales represent $82.6 billion in 2011.[6]

8.1.3 Example Market: Dyes and Pigments[7]

Figure 58 Pigments used in an oil suspension for paint
8.1.4 Clariant’s Challenge
Specialty chemical companies like Clariant are facing increased pressure from commoditization: the decrease in value of formerly specialty products caused by increased competition from emerging markets. This drives a need for specialty chemical companies to develop new products at an increased rate. To address this need, existing innovation practices must be challenged and refined.

Figure 9 shows a SWOT (Strengths, Weaknesses, Opportunities, Threats) matrix analysis for Clariant. Improved innovation practices coupled with Clariant’s already strong R&D capabilities would help to realize the opportunity to launch new products that could take advantage of rising global specialty markets.

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Weaknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wide product portfolio</td>
<td>Lack of Scale</td>
</tr>
<tr>
<td>Diversity across geographic markets</td>
<td></td>
</tr>
<tr>
<td>Strong R&amp;D capability</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Opportunities</th>
<th>Threats</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strategic acquisitions and</td>
<td>Intense competition</td>
</tr>
<tr>
<td>Launch of new products</td>
<td>New chemical product regulations in the</td>
</tr>
<tr>
<td>Rising global specialty chemicals market</td>
<td>European Union (REACH)</td>
</tr>
<tr>
<td></td>
<td>Risks associated with conducting business in foreign countries</td>
</tr>
</tbody>
</table>

Figure 59 SWOT Analysis [8]

It is important to emphasize that Clariant does not manufacture end consumer products. Their activity consists of producing chemicals or chemical processes that are necessary to produce end consumer products. They sell their products to business customers, who sell them to end consumers. For example, Clariant sells pigments to paint manufacturers, which then sell their products to painters, as shown in Figure 10.

Figure 60 Clariant’s Value Chain
8.1.5  A view from the inside

We set up an interview with Mark Schar, PhD, on November 26\textsuperscript{th}, which gave us key-insights and helped us clear some uncertainties about the relationship between chemical manufacturers, their business customers and the end consumer. Mark is Researcher and Lecturer at Stanford University and served as a senior VP at P&G during several years.

![Mark Schar](image)

Figure 61 Mark Schar

The first key take-away message from this interview was that Clariant trying to understand the end consumers better than their business customers is going to be a hard task. Companies like P&G have been for developing marketing and analytics tools to better understand the behavior of the end-consumer confronted to new products and his perception of innovation.

The second key message was that trying to understand 1\textsuperscript{st} tier customer might lead to much better results. The early integration of the customers in the R&D process of a technology can still be refined. A suggestion was that the length of the development cycles could be improved.

This discussion led us to draw a parallel with the growth of fast prototyping. If such a technology was available for the chemical industry then it could help to improve the current R&D processes for companies at Clariant. We needed to further delve this idea.
9 Appendix B: Innovation Benchmarking

9.1.1 Innovation at Clariant

Clariant is committed to improving its innovation. Clariant is building or planning to build two innovation centers in addition to its five existing global innovation centers. It is also cultivating collaborations with external research partners. In 2011, Clariant doubled its R&D staff with the purchase of Süd Chemie [9].

Despite these improvements, Clariant’s innovation strategy is self-focused and insular. While they have external research partners, much of their innovation focus is on improving internal R&D. A video on Clariant’s website that explains their innovation process claims that ideas are generated within Clariant’s R&D department [9]. We have found little evidence that the R&D department has any contact with customers, end users, or other stakeholders. The only customer feedback mentioned in the video is indirect communication through market research conducted by New Business Development unit. The new business unit gets about as much playtime as the Intellectual Property lawyers.

Direct communication with customers and stakeholders appears to be one-way. Clariant’s website has an impressive list of product groups and capabilities. It even has an innovations page dedicated to highlighting interesting new products. Figure #XX shows an example of a recent innovation. The product highlights include videos that describe, in relatively simple terms, how the product works and why it is important. However, there is no comment box or other feedback method.

![Advanced Denim Innovation from Clariant’s Website]

9.1.2 Open vs. Closed Innovation

Clariant’s innovation practices are characterized by closed innovation. The differences between open and closed innovation are best summarized in a presentation by Dr. Jochen Dubiel, Clariant’s Director of Strategic Communication Projects & Innovation Communication. Clariant’s emphasis on internal R&D, intellectual property law, and
apparent lack of direct collaboration with customers reveals a current focus on closed innovation. However, the existence of Dr. Jochen Dubiel’s presentation suggests that Clariant is aware of this focus and is trying to shift toward a focus on open innovation.

2. Closed Innovation vs. Open Innovation

<table>
<thead>
<tr>
<th>Closed Innovation Principles</th>
</tr>
</thead>
<tbody>
<tr>
<td>The smart people in the field work for us.</td>
</tr>
<tr>
<td>To profit from R&amp;D, we must discover it, develop it, and ship it ourselves.</td>
</tr>
<tr>
<td>If we discover it ourselves, we will get it to the market first.</td>
</tr>
<tr>
<td>If we create the most and the best ideas in the industry, we will win.</td>
</tr>
<tr>
<td>We should control our Intellectual Property, so that our competitors do not profit from our ideas.</td>
</tr>
<tr>
<td>Customers only lay a passive role in the innovation process.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Open Innovation Principles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not all the smart people in the field work for us.</td>
</tr>
<tr>
<td>External R&amp;D can create significant value, which internal R&amp;D is needed to claim some portion of.</td>
</tr>
<tr>
<td>We do not have to originate the research to profit from it.</td>
</tr>
<tr>
<td>If we make the best use of internal and external ideas, we will win.</td>
</tr>
<tr>
<td>We should profit from others’ use of our IP and buy others’ IP whenever it advances our business model.</td>
</tr>
<tr>
<td>The integration of our customers in the creation of ideas and products establishes significant additional value.</td>
</tr>
</tbody>
</table>

Figure 63 Closed vs. Open Innovation Slide from a Presentation by Clariant’s Director of Strategic Communication Projects & Innovation Communication [10]

9.1.3 Open Innovation Culture and Best Practices

Our project is part of Clariant’s attempt to shift to an open innovation strategy. Therefore we have benchmarked existing open innovation platforms and best practices.
Open innovation platforms like Open-Ideo allow a community of users with various profiles, location and expertise to work on challenges posted by IDEOS employees in a collaborative way. Among the users, we notice that we also find IDEO employees.

We became interested in an open Innovation platform called Innocentive, specifically targeting the chemical Industry. Innocentive represents 275,000 solvers working on challenges posted by Innocentive in exchange for monetary rewards.

On December 4th Innocentive and Synogenta, an Agricultural company based in Basel, Switzerland, organized a webinar explaining how to effectively implement an Open Innovation based solution.

The key driver for launching the open innovation platform at Synogenta was the imperative to reach beyond boundaries in a field where innovation is narrow. Yet the presenters highlighted the fact that connecting the people inside the company is also as important, as getting the culture mindset internally is capital.

Attracting users and making them solve your problems is about two things, the first one being: Asking the right problems. “Let’s cure cancer” is not a good question. Breaking this issue into smaller questions is a far better approach. OI is a toolbox to enhance the current innovation practice, not a miracle solution to change a company’s activity.

The second is the incentive and the rewards that are necessary to get an effective work from the users.
Building an effective platform with a sufficient external network of 3 or 4 thousand people can have a significant business impact. Open innovation has created impact on chemistry and biology questions, highly tangible areas. People like medical students and pharmacists are not in the industry but have great knowledge and great impact.
10 Appendix C: Surface Printer Code

```cpp
#include <InkShieldLite.h>

//initialize data (font) table - each letter is 12 rows
const int rowsPerChar = 12;

//table is 14 letters long
const int numOfChar = 14;
const int fontSize = numOfChar*rowsPerChar;

//"I <3 InkShield" stored in an array
const word font[fontSize] = {
    // 'I'
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    // '3'
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    // 'I'
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    // 'Space'
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    // 'T'
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    // '<'
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
    0b0000000000000000,
};
```
0b0000000011111110,
0b0000000110000011,
0b0000000110000011,
0b0000000110000011,
0b0000000110000011,
0b0000000110000011,
0b0000000110000011,
0b0000000110000011,
0b0000011111111111,
0b0001111111111111,
0b0000000000000000,

};

//initialize shield on pin 2
const byte pulsePin = 2;

void setup()
{
    setABCDPinMode(abcdA0A3,
OUTPUT);  //set the abcd pins as outputs
    pinMode(5, OUTPUT);
    pinMode(6, OUTPUT);
    pinMode(10, OUTPUT);
    pinMode(11, OUTPUT);
    pinMode(pulsePin, OUTPUT);         //set
the pulse pin as output

//loop 20 times (to print "I <3 InkShield"
20 times)
    for(int i=0;i<20;i++) {

        analogWrite(5, 200);
        digitalWrite(6, LOW);

        //loop the letters
        for(int
letter=0;letter<numOfChar;letter++) {

            spray_letter(letter);

        }

        //wait so there is some room between
prints
        delay(250);

        digitalWrite(5, LOW);

    }

}

void loop()
{
    //nothing here

}

void spray_letter(int letter)
{
    //loop through the rows of the letter
    for(int
row=0;row<rowsPerChar;row++){

        word strip =
font[(letter*rowsPerChar)+row];
//print the row
        spray_ink(strip);

    }

}

void spray_ink(word strip)
{
    //loop thru the strip
    for(byte i = 0; i <= 11; i++){

        fastABCDDigitalWrite(abcdA0A3, i,
HIGH);  //set abcd (nozzle address)
        fastDigitalWrite(pulsePin, HIGH);
        delayMicroseconds(5);  //pulse pin high,
wait 5us

digitalWrite(6, LOW);

analogWrite(10, 100);
digitalWrite(11, LOW);
delay(100);
digitalWrite(10, LOW);
digitalWrite(11, LOW);
analogWrite(6, 200);
digitalWrite(5, LOW);
delay(312);
digitalWrite(5, LOW);
digitalWrite(6, LOW);
delay(100);

delay(250);
digitalWrite(5, LOW);
delay(100);

delay(250);
}
fastDigitalWrite(pulsePin, LOW);
//pulse pin low
fastABCDDigitalWrite(abcdA0A3, i, LOW); //reset abcd
}
}
//wait to be sure we don't try to fire
nozzles too fast and burn them out
delayMicroseconds(800);

Printing Zigzag Pattern:

#include <InkShield.h>

//initialize shield on pin 2
InkShieldA0A3 MyInkShield(2);
//For shields set to A2A5 use
InkShieldA2A5 to initialize instead of
InkShieldA0A3
//InkShieldA2A5 MyInkShield(2);
void setup()
{
pinMode(5, OUTPUT);
pinMode(6, OUTPUT);
pinMode(10, OUTPUT);
pinMode(11, OUTPUT);
digitalWrite(5, LOW);
digitalWrite(6, LOW);
digitalWrite(10, LOW);
digitalWrite(11, LOW);
for(int i=0;i<3;i++){
analogWrite(5, 125);
digitalWrite(6, LOW);
for(int i=0;i<500;i++){
MyInkShield.spray_ink(0x0AAA);
}
digitalWrite(5, LOW);
analogWrite(6, 125);
}
delay(100);
analogWrite(10, 50);
digitalWrite(11, LOW);
for(int i=0;i<100;i++){
MyInkShield.spray_ink(0x0AAA);
}
digitalWrite(10, LOW);
analogWrite(11, 75);
digitalWrite(10, LOW);
delay(10);
digitalWrite(11, LOW);
delay(100);
}

void loop()
{
}

Printing Hysteresis Pattern:
#include <InkShield.h>

//initialize shield on pin 2
InkShieldA0A3 MyInkShield(2);
//For shields set to A2A5 use
InkShieldA2A5 to initialize instead of
InkShieldA0A3
//InkShieldA2A5 MyInkShield(2);

void setup()
{
  pinMode(5, OUTPUT);
  pinMode(6, OUTPUT);
  pinMode(10, OUTPUT);
  pinMode(11, OUTPUT);
  digitalWrite(5, LOW);
  digitalWrite(6, LOW);
  digitalWrite(10, LOW);
  digitalWrite(11, LOW);
}

double tnow;

void loop()
{
  tnow=0.01*millis();
  if(sin(tnow) < 0)
  {
    if (cos(tnow) > 0)
    {
      analogWrite(6, 200*(0-sin(tnow)));
      digitalWrite(5, LOW);
      analogWrite(10, 200*cos(tnow));
      digitalWrite(11, LOW);
    }
    else
    {
      analogWrite(6, 200*(0-sin(tnow)));
      digitalWrite(5, LOW);
      analogWrite(11, 200*(0-cos(tnow)));
      digitalWrite(10, LOW);
    }
  }
  else
  {
    if (cos(tnow) > 0)
    {
      analogWrite(5, 200*sin(tnow));
      digitalWrite(6, LOW);
      analogWrite(10, 200*cos(tnow));
      digitalWrite(11, LOW);
    }
    else
    {
      analogWrite(5, 200*sin(tnow));
      digitalWrite(6, LOW);
      analogWrite(11, 200*(0-cos(tnow)));
      digitalWrite(10, LOW);
    }
  }

  MyInkShield.spray_ink(0x0AAA);
}
Appendix D: Surface Printer Survey Results

What is the most important aspect of such event?

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neutral</th>
<th>Agree</th>
<th>Strongly Agree</th>
<th>Total Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Getting to know the cutting edge technology</td>
<td>50% (14)</td>
<td></td>
<td></td>
<td>39%</td>
<td>(11)</td>
<td>93% (28)</td>
</tr>
<tr>
<td>Meeting new people and expand the network</td>
<td></td>
<td>21% (6)</td>
<td>36% (10)</td>
<td>36%</td>
<td>(10)</td>
<td>93% (28)</td>
</tr>
<tr>
<td>Get new ideas for your own project</td>
<td>18% (5)</td>
<td>36% (10)</td>
<td></td>
<td>43%</td>
<td>(12)</td>
<td>93% (28)</td>
</tr>
</tbody>
</table>

Other?

<table>
<thead>
<tr>
<th>Responses</th>
<th>Blank</th>
</tr>
</thead>
<tbody>
<tr>
<td>97% (29)</td>
<td></td>
</tr>
<tr>
<td>3% (1)</td>
<td></td>
</tr>
</tbody>
</table>

*1 total response, 3% of submissions
Duration of the event?

<table>
<thead>
<tr>
<th>Duration</th>
<th>Percentage</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 day</td>
<td>68%</td>
<td>17</td>
</tr>
<tr>
<td>1 week-end</td>
<td>12%</td>
<td>3</td>
</tr>
<tr>
<td>1 week</td>
<td>20%</td>
<td>5</td>
</tr>
</tbody>
</table>

* 25 total responses, 83% of submissions

If yes

<table>
<thead>
<tr>
<th>Question</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neutral</th>
<th>Agree</th>
<th>Strongly Agree</th>
<th>Total Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>I want to invite my friends and form a team</td>
<td>39% (11)</td>
<td>32% (9)</td>
<td>18% (5)</td>
<td></td>
<td></td>
<td>93% (28)</td>
</tr>
<tr>
<td>I want to invite my colleagues and form a team</td>
<td>57% (16)</td>
<td>18% (5)</td>
<td>18% (5)</td>
<td></td>
<td></td>
<td>93% (28)</td>
</tr>
<tr>
<td>I would you join a team already formed</td>
<td>32% (9)</td>
<td>36% (10)</td>
<td></td>
<td></td>
<td></td>
<td>93% (28)</td>
</tr>
<tr>
<td>I would rather go there alone</td>
<td>29% (8)</td>
<td>46% (13)</td>
<td></td>
<td></td>
<td></td>
<td>93% (28)</td>
</tr>
</tbody>
</table>

If you are invited to a challenge aimed at new ideas with the use of the 3D printer shown in the video, would you go?

<table>
<thead>
<tr>
<th>Response</th>
<th>Percentage</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Interested</td>
<td>23%</td>
<td>7</td>
</tr>
<tr>
<td>Interested</td>
<td>40%</td>
<td>12</td>
</tr>
<tr>
<td>Neutral</td>
<td>37%</td>
<td>11</td>
</tr>
<tr>
<td>Not Interested (please explain)</td>
<td>0%</td>
<td>0</td>
</tr>
</tbody>
</table>

* 30 total responses, 100% of submissions
Other?

- 87% (26) responses
- 13% (4) responses
- Blank

*4 total responses, 13% of submissions

When you need help with a cutting-edge technical problem, where do you usually turn for help?

<table>
<thead>
<tr>
<th></th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neutral</th>
<th>Agree</th>
<th>Strongly Agree</th>
<th>Total Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>I google it</td>
<td>24% (7)</td>
<td>76% (22)</td>
<td></td>
<td></td>
<td></td>
<td>97% (29)</td>
</tr>
<tr>
<td>I search on academic DB</td>
<td>30% (9)</td>
<td>30% (9)</td>
<td></td>
<td></td>
<td>20% (6)</td>
<td>100% (30)</td>
</tr>
<tr>
<td>I go to online forums</td>
<td></td>
<td></td>
<td>37% (11)</td>
<td>40% (12)</td>
<td></td>
<td>100% (30)</td>
</tr>
<tr>
<td>I ask my professors</td>
<td></td>
<td></td>
<td>47% (14)</td>
<td>27% (8)</td>
<td></td>
<td>100% (30)</td>
</tr>
</tbody>
</table>
Other comments, suggestions

97% (29)
3% (1)
Responses   Blank

* 1 total response, 3% of submissions

Our sponsor company employees will be involved as members of this community and will bring this company’s expertise to the platform. Would you be willing to collaborate with them?

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neutral</th>
<th>Agree</th>
<th>Strongly Agree</th>
<th>Total Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>17% (5)</td>
<td></td>
<td>100% (30)</td>
</tr>
</tbody>
</table>

Column1: 40% (12) 37% (11)

Other?

100% (30)

0% (0)

Responses   Blank

* 0 total responses, 0% of submissions
The website could be an interface to a community of innovators. Would you be willing to try to tackle technical or business problems with the help of this community.

<table>
<thead>
<tr>
<th></th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neutral</th>
<th>Agree</th>
<th>Strongly Agree</th>
<th>Total Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical</td>
<td></td>
<td>42% (11)</td>
<td></td>
<td>35% (9)</td>
<td></td>
<td>87% (26)</td>
</tr>
<tr>
<td>Business</td>
<td></td>
<td>34% (10)</td>
<td>41% (12)</td>
<td>17% (5)</td>
<td></td>
<td>97% (29)</td>
</tr>
</tbody>
</table>

Would you take 20 minutes to fill out a detailed online profile in order to meet other people interested in developing applications for the 3D printer?

<table>
<thead>
<tr>
<th></th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neutral</th>
<th>Agree</th>
<th>Strongly Agree</th>
<th>Total Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Low - 5 High</td>
<td></td>
<td>33% (10)</td>
<td>40% (12)</td>
<td>20% (6)</td>
<td></td>
<td>100% (30)</td>
</tr>
</tbody>
</table>

Please list any ideas for applications you could create with this printer (max of 3):

- 77% (23)
- 23% (7)
- Responses
- Blank

* 7 total responses, 23% of submissions
What is your most recent profession?

- Student: 80% (24)
- Working in a start-up environment: 10% (3)
- Working in a large company: 7% (2)
- Other: 3% (1)

* 30 total responses, 100% of submissions

How familiar are you with printed electronics?

- I use them on a regular basis: 3% (1)
- I use them occasionally: 21% (6)
- I've heard of some, but never use any: 38% (11)
- I've never heard of any: 38% (11)

* 29 total responses, 97% of submissions

How intrigued are you by this new printing technology?

- Total Responses: 97% (29)

1 Low - 5 High

- 1: 21% (6)
- 2: 45% (13)
- 3: 17% (5)