DCBA Business Summary

Troy Astorino   Turner Bohlen   Craig Cheney   Gus Downs

May 9, 2013

1 Executive Summary

3D scanning has a wide variety of applications, from tolerance checking in machine shops, to measurement and modeling in art studios, but the high cost of current scanners keeps the technology from being used in many of these potential applications. Bringing down the cost and complexity of accurate 3D scanning opens it up to use by researchers, garage hobbyists, 3D printing enthusiasts, artists, independent product designers, small manufacturers, etc. 3D scanners have the potential to become the world's standard measurement and modeling tool, with a place in every shop, studio, and lab. Our team of 4 MIT undergrads, trained as as physicists, roboticists, programmers, mechanical engineers, and entrepreneurs, has the skills and vision necessary to build the 3D scanner that will make this vision a reality. Using the academically popular method of structured light 3D scanning, we can combine low-cost hardware components with state of the art software to create a low-cost and user-friendly 3D scanner that has the accuracy of systems an order of magnitude more expensive. With options at the high end, mobile, and entry level markets, full-field structured light 3D scanning is entering a phase of rapid market adoption.

Contents

1 Executive Summary **2**

2 Market Overview **4**
2.1 Market Setting 4
2.2 Customers 4
2.3 Competitors 4
2.3.1 Least-expensive high-accuracy scanners 5
2.3.2 Free scanners 5
2.3.3 Developing Scanners 5

3 Innovation and Approach **6**

4 Lessons Learned **7**

5 Plan of Action **7**
5.1 Customer Milestones 7
5.2 Product Milestones 8
5.3 Team Milestones 8
5.4 Financial Milestones 8

6 Risk Factors **8**

7 Team **9**

8 Financial Plan **11**

2 Market Overview

2.1 Market Setting

Digital 3D scanning is a large, established market, with an estimated market size of $530 million[4], projected to double in size by 2015[1]. Most of the products in this market are high-end and targeted at large corporations, costing tens of thousands of dollars. Reductions in component costs, advances in algorithmic efficiency, and increases in computing power now enable inexpensive 3D scanners that can achieve accuracy levels that are comparable to the expensive units.

Through building an accessible, affordable, desktop 3D scanner, we hope to expose a new, untapped market. The desktop 3D printing market has been experiencing rapid growth over the past few years, growing 240% each year from 2006 to 2011[13]. The primary customers for desktop 3D printers have been individuals: hobbyists, independent designers, artists, etc. We believe that this same market segment will buy an inexpensive desktop 3D scanner. In fact, we believe that 3D scanners will be the standard measurement tool used in shops, labs and studios. We believe that 3D scanners should be as common as a purchase as a cordless drill.

The 3D scanner needed by market has a set of requirements that we believe no other scanner on the market currently meets:

- It must be painless to use. From opening the box, the user needs to be able to plug the scanner into his computer, put an object in the scanner, press scan, and then have a 3D model appear on his computer.
- It must be affordable. The scanner cannot cost so much that it is a luxury to the user. We judge that the scanner must be in the $300-$600 price range.
- It must be useful. The scanner needs to have an accuracy high enough to not be a constraint on most machining processes or 3D printing processes. It cannot take too long to scan. It must be able to scan all objects that can be 3D printed, and a significant percentage of objects that would be used in a design.

2.2 Customers

The market segment we are targeting be divided into individual consumers and small ($<$ 10 people) enterprises.

The individual consumers we are targeting are hobbyists, enthusiasts, and artists. Many people have become excited about desktop 3D printing, and will be similarly excited by desktop 3D scanning. There is evidence for this in recent successful crowd-sourced fundings for desktop 3D scanning projects, and excitement surrounding 3D scanning announcements. Though much of the popular focus has been on scanning objects in order to get a model to print, other uses of 3D scanners can be marketed. A sculptor may want to display his work online, or send an early version of a sculpture to a colleague; our scanner allows him to do so with ease. A garage tinkerer may need to get the dimensions of an object he wants to incorporate into a larger project.

The small enterprises we are focusing on include research labs, product designers, and small machine shops. In research labs, it is often important to have models and measurements of objects being tested; while the 3D scanners available today would be an unaffordable luxury, ours would be low-cost enough to have a practical purpose. Product designers can make initial designs with physical materials, which are nicer to work with, and then scan them to get a usable CAD model. Small manufacturers and machine shops can use them in the same fashion that large manufacturers do: for automated verification of manufactured parts, as well as for designing parts with unknown dimensions.

2.3 Competitors

As 3D scanning technology has existed for a good deal of time, there are a number of 3D scanning products that exist. We believe that none of these address the needs of the market we are trying to target. A few other companies apparently have these same belief, and so there are a few competitors emerging that are entering in our target market.

We will explore the major competitors we believe we face by dividing them into 3 categories: the least-expensive high-accuracy scanners, free scanners, and emerging competitors. While companies in the first two categories aren't direct competitors, their products could be attractive to customers at the edges of our target market segment.

2.3.1 Least-expensive high-accuracy scanners

These competitors are the companies offering the least expensive 3D scanners that offer around 0.1 mm accuracy or better. The major companies in this range are the NextEngine scanner or Artec's 3D scanners. Our price ($500) will be significantly lower than these products, and our scanner will be easier to use than the NextEnginer scanner. The NextEngine costs over $3,000[10], and the least expensive Artec scanner costs $12,000[2]. Our scanner's accuracy will be in the same range as these products. Unlike these products, however, our scanner will only be able to scan objects that are under a certain size (1 ft^3). While the Artec scanners make scanning large objects fairly simple, scanning large objects with the NextEngine is very inconvenient, which is also true for other products in the their price range. Our scanner is clearly targeting a different customer than the Artec scanner, as $12,000 is more than our target customer is willing to pay. We differentiate from the NextEngine primarily in cost, but also in having more user-friendly, beautiful software. The NextEngine software can only run on Windows, and does not have the polish of a modern software solution.

2.3.2 Free scanners

These are scanning systems that are either free to use, or very cheap. They will be at a price lower than what we are planning. AutoDesk as an free app called 123D Catch–you take a series of images of an object and then it performs image reconstruction to generate a 3D model[3]. Some products (like Scanect) allow a customer to use a Kinect to perform 3D scanning, and Microsoft recently released KinectFusion, which turns the Kinect into a 3D scanner for anyone with the Windows Kinect SDK[6]. Although the accuracy of the scans made with these scans are not published, it is clear from looking at the showcase scans that they are not capturing sub-millimeter accuracy. That would make these scans limiting in when used with a 3D printer or for machining. They additionally more difficulty with highly specular objects than we will, and require user participation during the entire scanning process.

2.3.3 Developing Scanners

There are a couple competitors that have announced products but do not have products on shelves yet who seem to be targeting the same market segment that we are. CADScan successfully completed a Kickstarter project for a desktop 3D scanner that will be similar to ours in terms of target specifications and customers[5]. From the Kickstarter funding levels, it seems that they plan on charging at least £650 ($1000) for the scanner, a price we are planning on significantly undercutting. MakerBot also just announced at SXSW that they will be producing a desktop 3D scanner called the Digitizer[8]. The announcement was very nebulous on details, but given their 3D printer costs and their description of the Digitizer, we surmise that they will be charging around $1000. The Matterform Photon 3D scanner also had a successful crowd-funding campaing, raising $471,082 on indiegogo[12]. The Photon is certainly targeting the same market as us, but our scanner is differentiated from theirs by allowing a much larger maximum scannable volume: 1 ft^3 as opposed to $0.25 ft^3$. Their technology choice, striping with a single laser beam, will not allow them to increase the scannable volume without proportionally increasing the scan time. We do yet not know how our product can be differentiated from the CADScan and the Digitizer as they have not yet announced product specifics.

3 Innovation and Approach

Our product goals:

- Intuitive, clean software interface, accessible to users with limited to no CAD background
- .025mm accuracy - sub-machine tolerance
- 5 minute or less scan time
- 1 ft^3 scan volume
- $500 price point
- Plug and play software

To achieve these goals, we will use a technique called structured light scanning. The structured light scanning process consists of projecting a known image onto the object being scanned. This known image, usually stripes or a grid, will deform and using this deformed image, the object's surface can be reconstructed using triangulation. [7] This method does not require complex components; all that is necessary is an imaging system, such as digital cameras, and a projection system. Instead of using a traditional, expensive DLP projector, we are using a grating system to minimize costs.

There are tutorials online for how consumers can set up their own structured light scanners using a standard projector and a digital camera[9], but the amount of time required to calibrate the scanner and the hardware required makes the do-it-yourself approach both prohibitively difficult and expensive.

What we require for our product (a pre-calibrated, affordable, high-resolution 3D scanner) is a projection system, an imaging system, and the software to process the acquired data and generate a point cloud. The following discusses our development of the three subsystems so far.

Projection:

In order to get around the requirement of having a standard projector (for which the cheapest units retail for $300 in the US, $75 from China) we instead looked into the cheapest way that we could project a static, high-contrast image on our object. We looked into doing this using the interference properties of coherent laser light but instead opted for projecting a high contrast silhouette of a grating onto the object. Using simple geometric arguments, the factor limiting the contrast of the projected silhouette is the size of the light source (as one can imagine, the projected image is simply the image created by a point light source convolved over the size of the light source). Our approach: to focus a well-collimated light source down to a single point - effectively creating a point light source and then allowing it to propagate through the focal point and diverge to cover an area large enough to cover our whole object. All that this requires is a single lens and a collimated light source, for which we used a laser and a 15mm focal length lens from Thorlabs, but from initial testing we believe we can improve on the existing setup substantially while still keeping costs low. Employing a well-collimated, incoherent, white light source and a system of lenses should allow us to get rid of unwanted interference patterns and project a large enough image from less than 2 feet away.

Imaging:

The Smartphone industry has helped create a large demand for small, high resolution, inexpensive imaging sensor. These imaging sensors are the bare bones of digital cameras for only a fraction of the cost. The sensors are available for less than $10, even in small quantities, and can produce images in the 5-12 megapixel range[11]. The imaging sensors allow us to maintain affordability while still provide high accuracy. Microcontrollers are also at a point where they are cheap, but easily powerful enough to utilize the full potential of the sensor. Craig is currently doing development using a Cypress PSoC (Programmable System on Chip), which allows for fast prototyping, without the need for peripheral chips, as they can be programmed into the PSoC. This minimizes downtime wiring chips or designing Printed Circuit Boards, and reduces cost.

Software:

The initial software system is being built on top of two widely used open source libraries, OpenCV and Point Cloud Library. Both libraries are free for commercial use under the BSD license. The libraries allow us to leverage the significant infrastructure built for robotic applications. This is particularly valuable in using various algorithms for point cloud meshing. Error-mitigation during the meshing process is complex algorithmically, and building on top of existing software will make the process much easier.

The real value in the software is in making the system easy to use and accessible. The system needs to entirely pre-calibrated, and able to automatically re-calibrate over time. The user needs to be able to plug the scanner in and have it work. The software needs to be minimalistic and intuitive. A significant proportion of our target market won't have used CAD before, so it needs to interface with a bundled accesible model-viewing program. Of course it will support export of files to other CAD programs.

Although all of those features seem to be obvious candidates for inclusion, existing 3D scanning products do not have what qualifies as beautiful, modern software. Our team members' experience with web development and UI design will help us build dead simple software that will differentiate our scanner from the competition.

4 Lessons Learned

Imaging: Many of the issues that arose from prototyping have to do with the physical layout of the circuits. Many of the advanced sensors come in a format that is difficult to work with. The chips come in a Ball Grid Array package, which is not easily dealt with by prototyping. The grid consists of 56 balls of solder each spaced about 500-600μm apart, which are impossible to solder to directly; they must be reflowed onto a PCB. While this should not be a problem when dealing with the end product, it means that developmental tools are invaluable during initial phases.

Market study: When we first started exploring the 3D scanning space, NextEngine was the only company that had a viable product for consumers. However, we feel that the expense and difficulty associated with their product. There has been a significant debate over how large the consumer level 3D scanning market is. Experts in the industry are skeptical that there is demand outside of commercial settings, however the success of several recent crowdfunded projects, such as the Photon and CADScan, help to counteract their concerns.

5 Plan of Action

Following are the actions we will plan on completing, with more detail on tasks to complete over the summer.

5.1 Customer Milestones

Milestone	Date
Estimate consumer market demand via a Google Consumer Survey (or equivalent technique)	6/20
Choose product name and create logo as a reflection of desired brand image	8/1
Secure list of prototype testing partners	8/15

5.2 Product Milestones

Milestone	Date
Finalize the low-cost projection method that will be used in the system	7/1
Develop an IP strategy to protect crucial design components of the system, and file for provisional patents is appropriate	7/15
Complete alpha prototype of the system	9/1
Complete 2^{nd} alpha prototype of the system	10/1
Develop a list of components for a beta prototype, and select manufacturing partners to source parts from	11/1
Complete beta prototype	12/1

5.3 Team Milestones

Milestone	Date
Finalize team members' equity splits and vesting schedules, defining what will happen under different possible participation scenarios.	6/15
Bring in an additional team member with business experience to aid in business strategy, scaling, and marketing	9/1

5.4 Financial Milestones

Milestone	Date
Develop a high quality short and long pitch deck	7/1
1st order estimate of unit manufacturing costs at various build volumes using alpha prototype components	8/15
Secure funding in order to continue growing the business	9/1

6 Risk Factors

Risk Catergory	Risk	Probability of Risk Materializing	Risk Mitigation
Management Team	Having only technically oriented cofounders could leave us weak in terms of business strategy and entrepreneurial prowess	High	We must recruit another employee or cofounder who is business and marketing oriented
	Team unable to strategize operational plans to guide all steps of value chain	Medium	Proactively seek advice from experienced advisors and industry experts; implement monitoring and quality checks on a scheduled basis

Market	Over or under-estimated market size segmentation and location, such that operational and financial impact will be high	Medium	Target a statistically-rationalized need based audience. Perform a more thorough market analysis prior to product launch and design for operational flexibility to meet changes in demand
	Inability to capture targeted market, leading to lower sales than anticipated	Medium	Run an aggressive advertising campaign to attract new users. Verify that product aspects appeal to user-base by performing comprehensive usability tests
	Unexpected competition penetrates target market	Low	Focus on getting the product to market as quickly as possible. Track market trends and rising competition; design flexible and adaptable strategy to account for requirements to change aspects of product differentiation to stand apart
	Technical gap between potential customers and product use requirements hinders sales	High	It is essential that the product be "plug-and-play". We must balance giving the user adequate control over the settings, while at the same time make sure that the scanner can be run by someone with minimal experience
Finance	Unable to secure adequate funds for prototyping and scale-up	Dramatically High	Apply for accelerators, VC's and Angels. A working prototype will dramatic help in this regard
	Lack of adequate funds to fairly compensate desired talent	Low	Ensure that realistic and competitive salaries and benefits are included in all financial models
	Unmet supply and demand projections will lead to unbalanced revenues with fixed and variable costs, such that unit price exceeds initial estimate. This will lower market absorption and increase time to break-even	Medium	Identify the largest sources of cost and strategize how to best mitigate. Alternatively, depending on the market, we might find that our current target price point can be increased without severely impacting sales
Delivery	Difficulties with shipping and packaging	Low	Connect with experienced mentors or consultants, and keep delivery channels in mind during design

7 Team

Troy is graduating this June with majors in 16-ENG (concentration in Robotics) and 8B (concentration in Computational Learning Systems), and a minor in 14. In his internships he was worked as a programmer: on a Lockheed Martin development lead two summers ago and as the system architect for Monte Carlo simulation web service for SpaceX last summer. He also developed an odor localizing robot for CSAIL's

Robust Robotics group that used Bayesian inference to inform its search. Troy plays tennis for MIT and is a Freshman Leadership Program counselor.

Craig is pursuing his degree in 2A-6, Mechanical Engineering with a concentration in Control, Instrumentation and Robotics. He has worked extensively with robotics and mechanical design since freshman year of high school. This past semester his team won the 2.12, Introduction to Robotics, term Robo-Gymnastics competition. The team won their division, the overall competition, and was awarded “Best Design Award”. Additionally, Craig was awarded “Most Valuable Engineer” for his team. In addition to mechanical engineering, Craig is experienced with microcontrollers, software and embedded systems. Craig is currently president of his fraternity, captain of the varsity Waterpolo team, and a member of the national varsity swim team.

Gus is receiving his BS in physics from MIT this June. His focus has been on ultra-cold atomic physics, and he has worked in 5 different labs ranging from condensed matter physics to plasma physics. He sings with the Logarhythms, is a Freshman Leadership Program counselor, is a (half) Iron Man, and cooks a mean pork roulade.

Turner is pursuing his BS in physics at MIT. He has done extensive work as a web developer, and was the president of StartLabs as it has grown over the last year.

Troy and Gus have known each other since their freshman year, and have been co-counselors in the Freshman Leadership Program for the past 2 years. Turner and Troy completed a computational neuroscience study on human category learning together. Craig and Troy took the same robotics class, 2.12 Intro to Robotics, in the Fall of 2012 where they both placed in the top 5 out of 70 students.

Together, we have been working on this project together since January, as part of 6.S078, Entrepreneurship Project.

8 Financial Plan

Annual Growth Rate(to year 3): 2.4
Quarterly: 0.3579
Initial Annual Sales: 4000 units

DCBA

Revenue Projections
Years 1 to 5
($)

	Year 1	Year 2	Year 3	Year 4	Year 5
3D Scanner					
Number of Units	0	4,000	13,600	46,240	157,216
Price per unit	$ -	500	500	450	400
Total	0	2,000,000	6,800,000	20,808,000	62,886,400
Sales	0	2,000,000	6,800,000	20,808,000	62,886,400

Revenues by Months & Quarters
($)

Months	Year 1	Year 2	Year 3	Year 4	Year 5
Month 1	0	100,000			
Month 2	0	100,000			
Month 3	0	140,000			
Total 1st Quarter	0	340,000	1,014,067	3,103,046	9,378,093
Month 4	0	120,000			
Month 5	0	140,000			
Month 6	0	140,000			
Total 2nd Quarter	0	400,000	1,377,008	4,213,644	12,734,570
Month 7	0	160,000			
Month 8	0	200,000			
Month 9	0	200,000			
Total 3rd Quarter	0	560,000	1,869,848	5,721,733	17,292,350
Month 10	0	220,000			
Month 11	0	240,000			
Month 12	0	240,000			
Total 4th Quarter	0	700,000	2,539,077	7,769,577	23,481,387
Total for year	0	2,000,000	6,800,000	20,808,000	62,886,400
Average Revenue					
by Month	0	166,667	566,667	1,734,000	5,240,533
by Quarter	0	500,000	1,700,000	5,202,000	15,721,600

DCBA

Cost Projections

Years 1 to 5

($)

	Year 1	Year 2	Year 3	Year 4	Year 5
Per Unit Costs (Scanner)	$ 150.00	$ 140.00	$ 120.00	$ 110.00	$ 100.00
Number of Units	0	4,000	13,600	46,240	157,216
Total Unit Costs	$ -	$ 560,000.00	$ 1,632,000.00	$ 5,086,400.00	$ 15,721,600.00
Employees	5	10	20	30	35
Average Salary	$ 50,000.00	$ 100,000.00	$ 120,000.00	$ 150,000.00	$ 150,000.00
Total Labor Costs	$ 250,000.00	$ 1,000,000.00	$ 2,400,000.00	$ 4,500,000.00	$ 5,250,000.00
Facilities rate	$ 35.00	$ 35.00	$ 35.00	$ 35.00	$ 35.00
Square Footage per person	200	200	200	200	200
Total Facilities Cost	35,000	70,000	140,000	210,000	245,000
R&D Materials	100,000	200,000	100,000	2,000,000	5,000,000
Total Cost	$ 385,000.00	$ 1,830,000.00	$ 4,272,000.00	$ 11,796,400.00	$ 26,216,600.00
Net Income	(385,000)	170,000	2,528,000	9,011,600	36,669,800

References

[1] *3D Laser Scanning Market Expected to Double in Size by 2015*. 2011. URL: http://www.arcweb.com/press-center/2011-07-25/3d-laser-scanning-market-expected-to-double-in-size-by-2015.aspx (visited on 05/08/2013).

[2] *Artec Eva - Buy 3D Scanner - Artec 3D Scanners*. URL: http://www.artec3d.com/3d_scanners_for_professionals/artec-eva/buy/ (visited on 05/08/2013).

[3] *Autodesk 123D - 123D Catch turn photos into 3D models*. URL: http://www.123dapp.com/catch (visited on 05/08/2013).

[4] Prathima Bommakanti. *Analysis of the Global Optical Digitizer and Scanner Market: Need for Greater Accuracy and Speed Drives Demand*. Tech. rep. Frost & Sullivan, 2012.

[5] *Desktop 3D Scanner by CADScan Kickstarter*. URL: http://www.kickstarter.com/projects/621838643/desktop-3d-scanner (visited on 05/08/2013).

[6] *Kinect Fusion*. URL: http://msdn.microsoft.com/en-us/library/dn188670.aspx (visited on 05/08/2013).

[7] Douglas Lanman and Gabriel Taubin. "Build Your Own 3D Scanner: 3D Photograhy for Beginners". In: *SIGGRAPH '09: ACM SIGGRAPH 2009 courses*. New Orleans, LA USA: ACM, 2009, pp. 1–87.

[8] *MakerBot Digitizer*. URL: http://store.makerbot.com/digitizer.html (visited on 05/08/2013).

[9] Kyle McDonald. *Structured Light 3D Scanning*. 2009. URL: http://www.instructables.com/id/Structured-Light-3D-Scanning/step2/Theory-Three-Phase-Scanning/.

[10] *NextEngine 3D Laser Scanner*. URL: http://www.nextengine.com/products (visited on 05/08/2013).

[11] Gina Roos. *CMOS Image Sensors Continue to Advance*. URL: http://www.digikey.com/us/en/techzone/sensors/resources/articles/CMOS-Image-Sensors-Continue-to-Advance.html (visited on 05/08/2013).

[12] *The Matterform 3D Scanner — Indiegogo*. URL: http://www.indiegogo.com/projects/the-matterform-3d-scanner (visited on 08/05/2013).

[13] T.T. Wohlers and Inc Wohlers Associates. *Wohlers Report 2012: Additive Manufacturing and Three Dimensional Printing State of the Industry Annual*. Wohlers Associates, 2012. ISBN: 9780975442975. URL: http://wohlersassociates.com/2012report.htm.