

October 6th, 2015

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, BC V5A 1S6

Re: ENSC 440 Functional Specification for the Dot Light Canvas

Dear Dr. Rawicz

The attached document is the functional specification for Art Tech's project, the Dot Light Canvas. The Dot Light Canvas is a new and innovative art canvas that uses LED light in the place of paint. It will be used by new and seasoned artists alike to create unique artistic expressions that are bright and creative.

The attached functional specification document outlines the general, physical, electrical and mechanical requirements of the Dot Light Canvas prototype and production system. It will also include the safety and sustainability requirements of our design.

The Art Tech team is made up of four Simon Fraser University engineering students; Zachary Cochrane, Dana Sy, Aman Shoker and Bhavit Sharma. Together we hope to create a working prototype of our Dot Light Canvas that will not only fulfill all requirements contained in this document but also be fun to use and inspire confidence in the final design. If you have any questions or comments about this document or our project, please contact me at zwc@sfu.ca or through phone at (778) 378-6019.

Sincerely,



Zachary Cochrane
CEO and Primary Contact
Art Tech

Enclosure: *Functional Specification: The Dot Light Canvas*



Functional Specification The Dot Light Canvas

Project Team: Zachary Cochrane
Dana Sy
Aman Shoker
Bhavit Sharma

Contact Person: Zachary Cochrane
zwc@sfu.ca

Submitted To: Dr. Andrew Rawicz
Professor Steve Whitmore
Faculty of Applied Sciences
Simon Fraser University

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Executive Summary:

The ability to create art is intrinsic to humanity. As human beings, we are constantly looking for ways to express ourselves, whether it be through music, movies, painting or pottery. Artistic expression is incredibly important to what it means to be human.

Art Tech is a company that understands the importance of creativity, and it is our mission to bring artists new and exciting ways to express themselves. Our product, the Dot Light Canvas, is an innovative art form that uses LED light in the place of paint. Our product will give artists a vibrant outlet that will shine as bright as their imagination.

This document outlines the functional requirements, safety and sustainability standards of the Dot Light Canvas prototype. Additional requirements have been included for the final product, which will begin development after successful completion of the prototype system.

The Dot Light Canvas system will follow a modular design paradigm, and will be developed and tested as multiple subsystems before being integrated together as a final product. Each subsystem must fully adhere to the outlined functional requirements for the prototype to be considered complete. These subsystems, which each represent a single aspect of the project, include the following:

- Infrared Touch Screen and Frame
- LED Matrix
- Smart Stylus
- System Controller

Testing will be conducted on each subsystem following the guidelines and requirements listed within this document, the Dot Light Canvas Functional Specification. Upon failure of a test, the offending subsystem will be revisited and revised until all tests are passed successfully. Once all subsystems have successfully passed their functional requirements tests, the system as a whole will be tested, following the same procedure outlined above.

In addition to the functional requirements of the product, the Dot Light Canvas must adhere to a specific set of safety and sustainability standards. Compliance with these standards coupled with successful completion of the testing plan indicates the completion of the prototype product. The prototype is scheduled for a completion date of December 18th 2015.

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1.0 Introduction

The Dot Light Canvas is an electronic painting canvas that uses Light Emitting Diodes (LEDs) for illumination of the canvas. The canvas will consist of an infrared (IR) touchscreen mounted over a cloth painting canvas that will overlay an LED matrix. Users will be able to 'paint with light' by applying a smart stylus to the IR touchscreen, activating the LEDs behind it to illuminate the canvas in a variety of user specified colors. The functional requirements of the Dot Light Canvas are described in the following pages of this document.

1.1 Scope

This document lists the functional requirements that must be met by the Dot Light Canvas at various stages in its development, including its proof-of-concept design and the final product design. All requirements contained in this document must be met by the Dot Light Canvas for it to be considered a functioning product.

1.2 Intended Audience

This document is intended for use by the Dot Light Canvas design team of Art Tech. All members of the team shall refer to this document as both a development and testing guideline. Prior to the design and implementation of any subsystems of the Dot Light Canvas, this functional specification must be consulted and its requirements kept in mind. After implementation has been completed, the subsystem must be checked against the corresponding requirements contained in this document. Any requirements that are not met indicate a flaw in system design, which will result in revisions of the system until it adheres to all listed requirements.

1.3 Classification

In the proceeding sections of this document, we will present a number of functional requirements. They will be presented in the following format:

[Rn-p] A functional requirement.

Where n is the functional requirement number and p is the priority of the requirement, which will receive one of the three following values:

- I** The requirement strictly applies to the proof-of-concept design
- II** The requirement applies to both the proof-of-concept design and the final product design
- III** The requirement strictly applies to the final product design

2.0 System Requirements

2.1 System Overview

Dot Light is a new way for creators to express their artistic abilities, using vibrant colorful lights. The two main components a user of the Dot Light system will interact with are the smart stylus and the canvas. Both the smart stylus and the canvas will need to be in constant communication with each other via a Bluetooth connection.

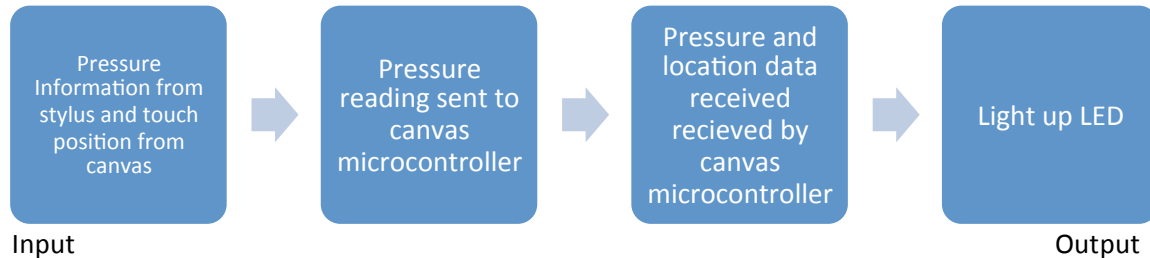


Figure 1: High-Level Functional Diagram

The canvas is made up of the following components, which are also outlined in Figure 3, found on page 4:

- LED matrix, mounted on a lightweight backboard
- A reflective grid overlaying the LED matrix, with each square housing a single LED
- A cloth painting canvas overlaying the reflective grid and the LED matrix
- An IR touchscreen, overlaying the LED matrix, the reflective grid and the cloth painting canvas
- A chassis that houses all the above components and the microcontroller and power supply.

The above components combine to create the canvas on which the user will draw. The prototype of the Dot Light Canvas will consist of 24 columns of 43 LEDs each for a total of 1032 LEDs, but the final product is expected to have a higher resolution still. The reflective grid will focus the LED light forwards, limit color mixing between the LEDs and give the canvas a pixel-art-like appearance, while the cloth painting canvas keeps the look of a painting.

The smart stylus is the main way the user interacts with the canvas. The prototype smart stylus will have the following features:

- A smooth, rubber, pressure sensitive tip for interacting with the IR touchscreen
- An LED embedded in its shaft that will display the current color selection

- A button immediately below the LED that brings up a color selection wheel on the canvas, handled as follows:
 - The user presses the color selection button on the smart stylus
 - The current display on the LED matrix is replaced with a color selection wheel
 - The user selects a color by touching the pen to the IR touchscreen, which changes the color selection in the embedded LED and dismisses the color selection wheel on the LED matrix
- A button on the opposite end of the smart stylus. When depressed, the stylus is in paint mode. Otherwise, it is in erase mode.
- Bluetooth communication with the controller embedded in the canvas frame

The smart stylus, when applied to the IR touchscreen, will light up the LED behind it with the color stored in the pen and with a brightness that corresponds to the pressure applied to the canvas screen. The production smart stylus will also feature a rubber grip as well as a more pleasing aesthetic than the prototype, which a rechargeable battery and a chassis that has been machined instead of 3D printed.

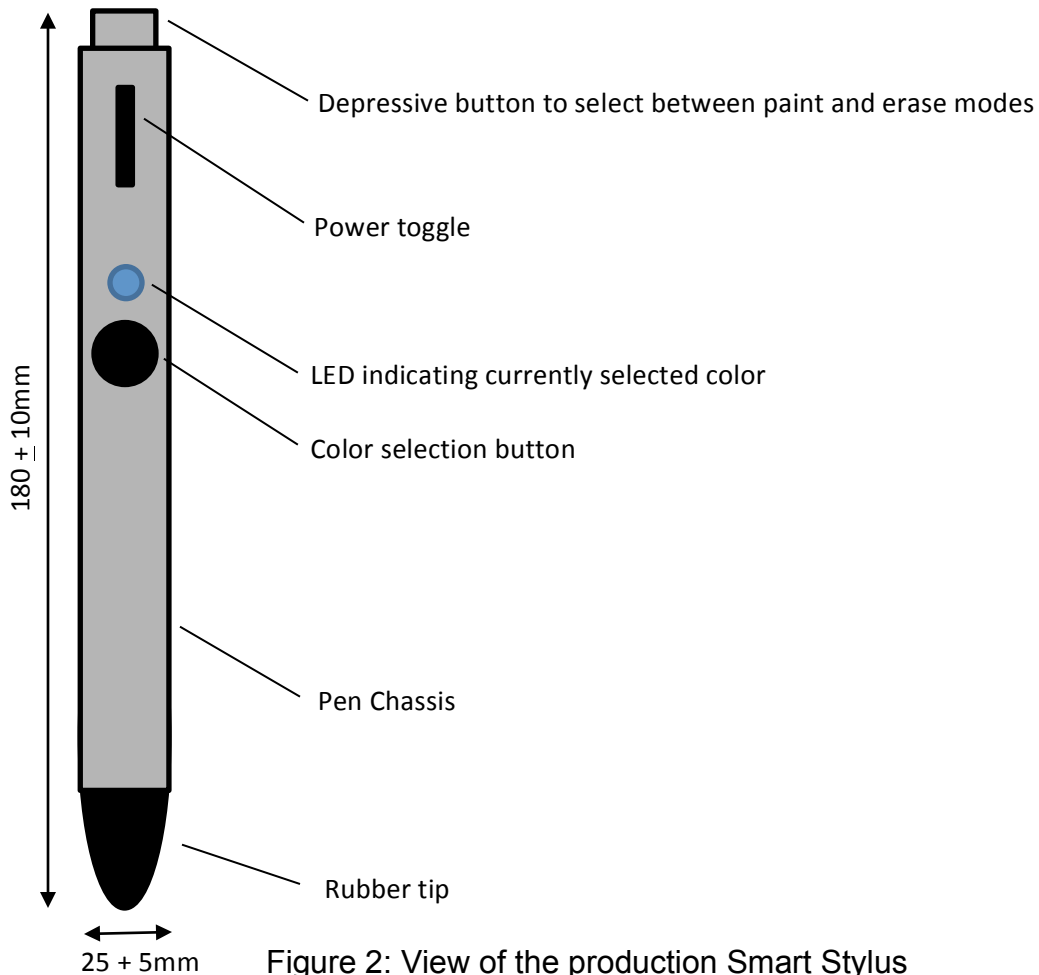


Figure 2: View of the production Smart Stylus

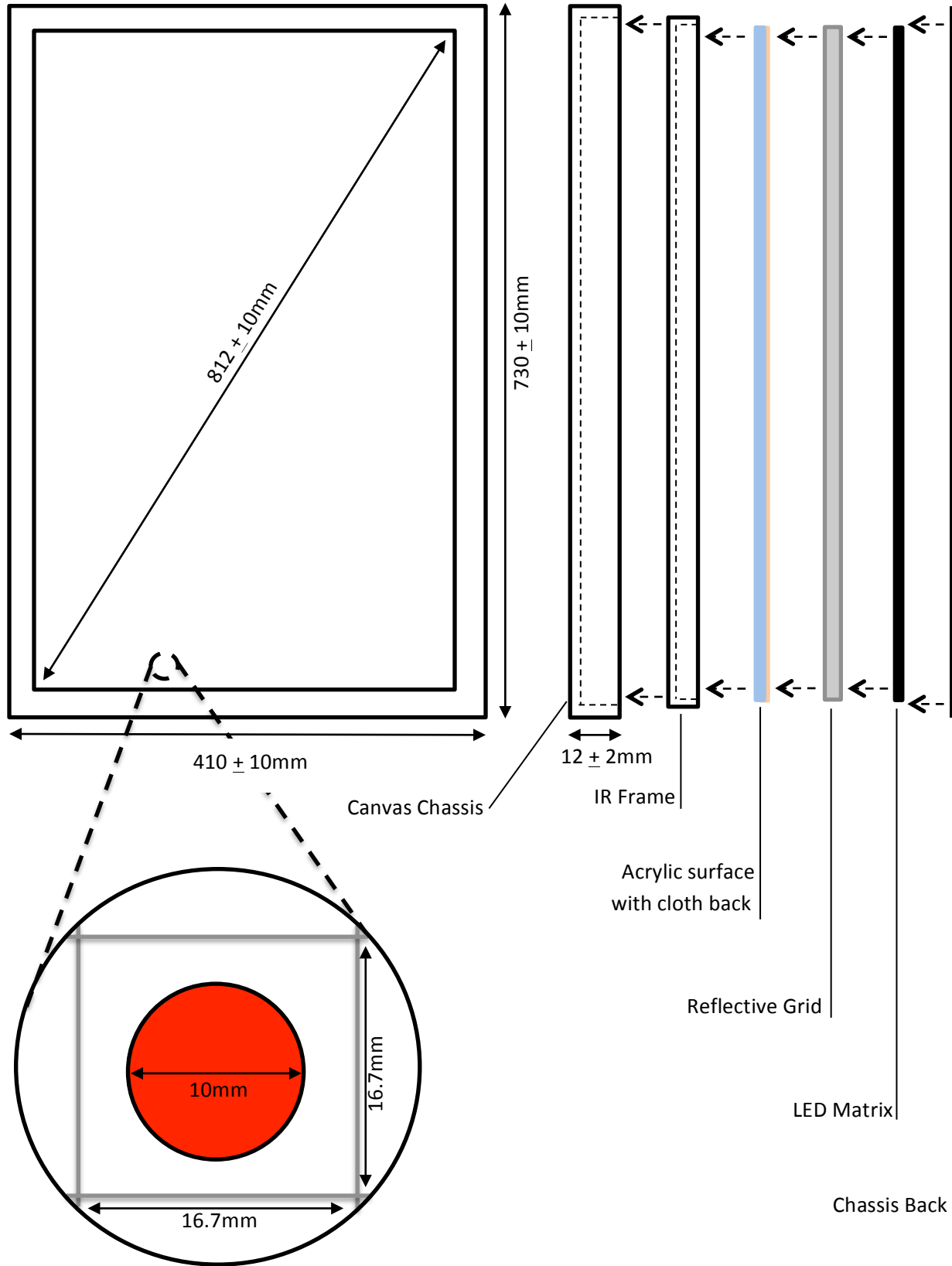


Figure 3: Front and Side view of production Dot Light Canvas

Figures 2 and 3 above show the estimated dimensions and build of the Smart Stylus and Dot Light Canvas, respectively. The prototype versions will adhere as closely as possible to these dimensions, but we expect an increase in size of up to 25% for the pen and 10% for the canvas due to machining limitations and component sizes.

2.2 General Requirements

Below are the general requirements that the Dot Light Canvas must meet before being considered complete.

- [R1-II] The canvas and smart stylus will each have a switch to turn them on and off.
- [R2-III] The retail price of Dot Light should be under CDN\$600.
- [R3-II] The canvas should only have one power cable to the wall.

2.3 Physical Requirements

Physical requirements include size, weight and appearance of the Dot Light Canvas system. Note, the Dot Light system is intended to be scalable. Therefore other sizes of the canvas may not follow the physical requirements below. These requirements are for the prototype and production versions of the 32" canvas.

- [R4-III] The canvas should hide all electronics from the user, simply appearing like a framed blank canvas when powered off.
- [R5-I] The canvas should not exceed 420mm x 740mm x 14mm in dimension.
- [R6-I] The canvas should not exceed 5 kilograms in weight
- [R7-III] The stylus should hide all electronics from the user.
- [R8-II] The stylus should not exceed 30mm in diameter and 190mm in length
- [R9-II] The stylus should not exceed 500 grams in weight.

2.4 Electrical Requirements

Electrical requirements include considerations of how both the canvas and smart stylus will be powered, and also includes other relevant subjects such as battery life and charging details.

- [R10-III] The Smart Stylus should have a rechargeable battery.
- [R11-III] The Smart Stylus should have a battery life of at least 10 hours.
- [R12-III] The Smart Stylus should be easily recharged from the canvas.
- [R13-II] The Canvas shall draw power from a single power supply connected to a standard wall outlet.
- [R14-II] The power supply should be sufficient enough to power up to 1200 LEDs at maximum intensity.
- [R15-II] Each section of LEDs should have fuses to avoid blowing other LEDs in case of power failure.

2.5 Mechanical Requirements

Mechanical requirements outline all moving and detachable parts of the Dot Light Canvas System.

- [R16-III]** The canvas should include a stand, which is able to adjust its height, swivel and angle.
- [R17-III]** No electronic components should be accessible to the user without unscrewing the chassis back from the canvas, which will void any warranty included with the product.
- [R18-III]** No electronic components should be accessible to the user without dismantling the smart stylus, which will void any warranty included with the product.
- [R19-II]** The components of the canvas need to be secured and locked in place within the canvas chassis to avoid damage during transit.
- [R20-III]** The smart stylus shall have a removable cover allowing the user to change the rechargeable battery, if needed.

2.6 Environmental Requirements

Environmental details give insight into what sort of environment the canvas shall be used in. The requirements in this section outline what is considered a normal working environment for the Dot Light Canvas system.

- [R21-II]** The canvas should operate normally between 0°C to 50°C.
- [R22-II]** The canvas should operate normally in the humidity range of 0% to 70%.
- [R23-II]** The canvas should generate less than 20 dB of noise.
- [R24-III]** Advertisement versions of the Dot Light Canvas should be weather sealed.

2.7 Performance Requirements

Performance requirements are put in place to ensure that a user interacting with the Dot Light Canvas does not have any issue with the quality of the product, including its speed, interactivity and responsiveness.

- [R25-II]** The canvas should not light up 2 or more LED lights simultaneously.
- [R26-II]** The canvas should respond to user input within 20ms, lighting up an LED within the same timeframe.
- [R27-II]** The Smart Stylus mode and color buttons should respond to user input within 20ms.
- [R28-II]** An LED should begin to emit light when a pressure of approximately 0.2 kilograms per LED area is applied by the smart stylus.
- [R29-II]** An LED light should reach maximum intensity when a pressure of approximately 0.8 kilograms per LED area is applied by the smart stylus.

2.8 Usability Requirements

Usability requirements outline what requirements the system must meet to ensure the canvas is easy to use and comfortable to work with under normal conditions.

- [R30-II] The heat output from the Dot Light Canvas should not exceed 40°C, as to not be uncomfortable to the user.
- [R31-II] The canvas should be easily cleanable with a wet cloth.
- [R32-III] The canvas should be able to be connected to a PC for firmware upgrades and internet services.
- [R33-II] When powered on, the light from the canvas should be easily distinguishable from light pollution in a normally lit room.
- [R34-II] When powered on, the light from the canvas should not be so strong as to cause the user discomfort when used in a dark room.

2.9 Reliability Requirements

The Dot Light Canvas must be able to work for a minimum amount of time before failing, otherwise it will be considered defective. The requirements below outline what Art Tech considers to be an effective and reliable product.

- [R35-II] The acrylic touch surface of the canvas should be strong enough to handle moderate abuse from users.
- [R36-II] The acrylic cover should be strong enough to resist scratches from repeated use of the stylus.
- [R37-II] The canvas should have an idle state that will turn off the LEDs after 5 minutes of inactivity.
- [R38-III] The smart stylus tip shall be able to withstand an applied force of up to 10 kilograms.
- [R39-III] The smart stylus must be able to survive a fall from a minimum height of 1.5 meters.
- [R40-II] The smart stylus must maintain a Bluetooth connection with the canvas in a minimum 3 meter radius.
- [R41-III] The Dot Light Canvas system shall have a minimum operational life of 10,000 hours.

2.10 Engineering Standards

The Dot Light Canvas must adhere to the engineering standards below before being introduced to the retail market.

- [R42-III] The Dot Light Canvas shall comply with the EDEE Act (Environmental Design of Electrical Equipment Act). [1]
- [R43-III] The Dot Light Canvas shall conform to IEC-61508 functional safety standards. [2]

- [R44-III] The Dot Light Canvas shall conform to standard C22.2 No. 207-15 for Portable and Stationary Electric Signs and Displays. [3]
- [R45-III] The advertisement versions of the Dot Light Canvas shall conform to standard CAN/CSA-C22.2 No. 60950-22-07 (R2012) for Equipment to be Installed Outdoors. [4]
- [R46-III] The Dot Light Canvas shall conform to standard CAN/CSA-C22.2 No. 60065-03 (R2012) for Audio, Video and Similar Electronic Apparatus – Safety Requirements. [5]
- [R47-III] The Dot Light Canvas shall conform to the IEEE 802.15 Wireless Personal Area Network Standards for Bluetooth communication. [6]

2.11 Luxury Functions

Luxury Functions include ideas that are desired, but are not required for the system to be considered complete, as well as stretch goals that future iterations of the Dot Light Canvas may include.

- [R48-III] Artworks can be saved and loaded into an SD card or the cloud.
- [R49-III] Canvas can sport creation and playback of animations.
- [R50-III] LEDs will be able to mix colors and intensities instead of overwriting current LED value.
- [R51-III] Canvas will have an auxiliary input to play music and have an equalizer animation.
- [R52-III] Every component should be modular for an upgrade path.
- [R53-III] The stylus shall be able to scan existing colors on the canvas as opposed to using a color wheel to select color.

3.0 Safety and Sustainability

Art Tech realizes the importance of safety and sustainability. Therefore, special consideration must be given to the requirements with regards to these two sections.

3.1 Safety Requirements

The Dot Light canvas contains numerous electrical components which can be hazardous. Ensuring product safety is Art Tech's top priority. All individually purchased parts of the Dot Light Canvas system have been certified by the CSA and any components designed by Art Tech will also be tested and will comply with all relevant safety standards.

- [R54-III]** All Canadian components purchased for use by the Dot Light Canvas system shall be CSA certified.
- [R55-III]** All international components purchased for use by the Dot Light Canvas system shall be CSA International or ANSI certified.
- [R56-III]** Components designed by Art Tech shall undergo testing to ensure compliance with CSA standards.
- [R57-III]** All electronic components, wiring and power connections shall be enclosed and unreachable from the user.
- [R58-III]** All electronic components, wiring and power connections shall be enclosed in water resistant material.
- [R59-II]** The Dot Light Canvas shall not have any sharp or jagged edges that could cause bodily harm to a user with normal use.

3.2 Sustainability Requirements

Nowadays there is a greater need to design products that take into consideration the social, economic and ecological impacts associated with the materials and methods used to construct products. At Art Tech we intend to design and engineer the Dot Light Canvas with sustainability in mind. It is of the utmost importance that after the product life cycle the components of the Dot Light Canvas are not issued to a landfill.

The Dot Light Canvas has many different electronic components, and Art Tech is determined to pursue a cradle to cradle (C2C) lifecycle plan which will succeed in refurbishing, repurposing or recycling the assembled components to reduce the products ecological and economic footprint.

- [R60-III]** All power sources, chassis materials, and electronic parts used must be made of recyclable components.

- [R61-III]** Biodegradable Polylactic Acid Filament (PLA) shall be used in the construction of the Smart Stylus and Canvas chassis.
- [R62-II]** All soldering used in the Dot Light Canvas system shall be lead free.
- [R63-III]** All electronic components, including all microcontrollers, LEDs, resistors and buttons should have the ability to be unsoldered and recycled in other devices.
- [R64-III]** All electronic components, including all microcontrollers, LEDs, resistors and buttons should be made of recyclable materials, in the event that the components no longer function as desired after the lifespan of the system has expired.
- [R65-III]** The IR frame and acrylic screen should have the ability to be disconnected and recycled in other devices.

4.0 IR Frame

The IR frame records the position of touch using Infrared sensors and sends the data via USB to the microcontroller. This data, combined with data from the smart stylus, will be sent to the canvas microcontroller, which will determine the color, location and intensity of the LEDs being painted.

4.1 General Requirements

- [R66-II] The frame shall successfully record the position of touch.
- [R67-II] The frame shall support a minimum of 300 reads per second.
- [R68-II] The frame shall successfully transmit the recorded position to the microcontroller within 10ms.
- [R69-I] The frame shall connect to the controller via USB 2.0.
- [R70-II] The minimum width to record a touch from the smart stylus should be no less than 3mm.
- [R71-III] The frame shall ignore touches sent to it from any source but the smart stylus.
- [R72-I] The device shall be able to support no less than 60,000,000 single point touches per centimeter square of area.
- [R73-I] Power shall be supplied by a single USB connection from the canvas microcontroller.
- [R74-II] Power consumption shall not exceed 2 W while operating and 250 mW while on standby.

4.2 Physical Requirements

- [R75-I] The dimensions shall be no greater than 740.1 mm x 433.3mm x 8.7mm.
- [R76-I] The screen size (diagonally) shall not exceed 805.6mm.
- [R77-I] The weight of the frame shall not exceed 1600 grams.

5.0 Smart Stylus

The smart stylus is a major component of our product, as it is the only way through which the user can interact with the canvas. It will support connection via Bluetooth to the canvas and serves many important functions, including the following:

- Bringing up the color menu on the canvas to choose what color you want to use to paint
- Changing the mode from paint to erase or vice versa
- Feeds the user information through the embedded LED and power button
- Is the only tool by which the user can interact with and paint on the canvas

5.1 General Requirements

- [R78-II] The smart stylus shall enable the canvas to turn on an LED light when touched to the canvas glass.
- [R79-II] The smart stylus shall have the ability to bring up the color wheel to select a color.
- [R80-II] The smart stylus tip shall be pressure sensitive through the use of a force sensor resistor.
- [R81-II] The smart stylus shall be connected wirelessly to the canvas via Bluetooth.
- [R82-II] The smart stylus should have the capability to turn off specific LED lights on the canvas.

5.2 Physical Requirements

- [R83-II] An LED on the stylus shall represent the color selected to paint on the Dot Light canvas.
- [R84-III] An LED on the stylus shall display the status of Bluetooth connection of the stylus to the canvas.
- [R85-II] The diameter of the smart stylus shall be no more than 30 mm and the length shall be no more than 190 mm.
- [R86-II] A button on the stylus shall allow the user to bring up a color wheel on the canvas.
- [R87-II] A button on the stylus shall allow the user to switch between paint and erase mode.
- [R88-II] The stylus should be comfortable, small, and light enough for the user to hold in one hand.

6.0 LED Array

The LED lights are the fundamental component of the Dot Light Canvas, providing the illumination for the drawings. The LEDs provide a full range of RGB colors, offering artists an artistic canvas like no other where they will have the ability to create, modify and delete their painting with a simple touch of the stylus.

The Dot Light Canvas uses NeoPixel [7] LED lights to populate its display. For the prototype, the LEDs will be arranged in a 24 x 43 matrix, for a total of 1032 LEDs. Production versions of the Dot Light canvas must use this as a minimum resolution, and may go as high as twice the number of LED lights.

6.1 General Requirements

- [R89-II] Each individual LED shall be able to display the full RGB color spectrum independent of the other LEDs.
- [R90-II] Each individual LED shall be able to fluctuate in brightness from off to fully powered independent of the other LEDs.
- [R91-II] Each individual LED shall have a minimum lifetime of 10,000 hours.

6.2 Physical Requirements

- [R92-II] Each individual LED shall not exceed 10mm in size.
- [R93-II] The LED matrix shall contain a minimum of 1000 LED lights.
- [R94-II] The LEDs in the LED matrix shall be equidistant from one another, and this distance must not exceed 20mm.
- [R95-II] The LED matrix shall cover the entire IR touchscreen, leaving less than 20mm of distance between the outside LEDs and the frames inner edge at all times.

6.3 Electrical Requirements

- [R96-II] The LEDs shall receive power from the Canvas Power Supply.
- [R97-II] The LEDs shall operate at 5V and draw no more than 60mA of current each, when at 100% intensity.

7.0 Microcontrollers

Microcontrollers are small computers that can be programmed to receive input from sensors and translate it to output sent to peripherals. Various microcontrollers have different processor speeds and memory sizes. Choosing the optimal microcontroller depends on what the controller is required to achieve, and having a microcontroller that is too powerful or too weak for the project requirements can be detrimental to the project budget or overall quality.

The Dot Light Canvas will require two different microcontrollers; one for the canvas and another for the smart stylus. The prototype however, will also use an array of three additional microcontrollers to control the LED lights. These controllers will communicate with the main microcontroller for the canvas.

7.1 General Requirements

- [R98-III]** The Dot Light Canvas system should require no more than two distinct microcontrollers; one for the smart stylus, and another for the canvas.
- [R99-II]** The canvas microcontroller should have enough memory to hold the specific color and intensity values for a minimum of 1200 LEDs.
- [R100-III]** The canvas microcontroller should have secondary memory available to hold a minimum of twenty additional sets of LED values, each set corresponding to a saved painting.
- [R101-II]** The smart stylus microcontroller should be fast enough to process all smart stylus inputs (force, color indicator, modes) within 20ms.

7.2 Physical Requirements

- [R102-III]** The smart stylus microcontroller should be sufficiently small that it can fit inside the shell of the smart stylus without any protruding or visible parts.
- [R103-II]** The canvas microcontroller should be secured to the inside of the canvas frame and hidden from user view.

8.0 Conclusion

The Dot Light Canvas is a system of many parts. From physical to mechanical to safety and standards there are many requirements that must be considered and upheld during system design. Individual parts too, such as the LED Matrix, the IR frame, the smart stylus and the microcontrollers all have various needs that must be considered.

This document has outlined the functional requirements for the proof of concept and production versions of the Dot Light Canvas. It will be used throughout the design and development cycles as a reference and testing platform to ensure all requirements are met. The proof-of-concept is currently in the development phase and is expected to be complete by December 18th, 2015.

9.0 Glossary

- Adafruit – Online vendor that designs and sells a variety of electronic components, including the NeoPixel LED strips and their controllers
- Art Tech – Company that proposed the Dot Light Canvas. Includes the four founding members, Zachary Cochrane, Dana Sy, Bhavit Sharma, and Aman Shoker
- Bluefruit – Bluetooth microcontroller designed and sold by Adafruit, used to control the Smart Stylus input and communication with the Dot Light Canvas
- C2C – the Cradle to Cradle design approach is the view that a system should be designed such that all components can be reused or recycled in one way or another at the end of the systems lifespan
- Dot Light Canvas – A proposed LED Painting system that allows users to ‘paint with light’. Consists of an array of LED’s behind an IR touch screen, controlled by a smart stylus.
- FadeCandy – NeoPixel Microcontroller designed and sold by Adafruit, used to control up to 512 individual LEDs in 8 strips of 64 each
- IR Touchscreen – Infrared touch screen. Uses infrared lasers coupled with sensors to detect where a touch has been made.
- LED – Light Emitting Diode. A light source consisting of a p-n diode that emits light when activated. Known for its intense luminosity and vibrant color.
- NeoPixel – Programmable RGB LED designed and sold by Adafruit
- PLA – Polylactic Acid Filament, a biodegradable plastic commonly used as a source of 3D printing material.
- Raspberry Pi 2 – General purpose microcontroller designed and sold by the Raspberry Pi Foundation which will be used to control the Dot Light Canvas
- RGB – An additive color model which adds Red, green and blue hues together of varying intensity to produce a large number of different colors.
- Smart Stylus – The device that controls the Dot Light Canvas. A stylus that, when applied to the canvas, turns the LED’s behind it on and off, depending on its mode. Has color controls and the ability to switch modes between paint and erase built right in.

References

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