Product Requirements Document
Multi-spectral Imaging Device

Customer: Dr. Roy S. Berns
Engineers: Joseph DiFabio, Maggie Han, Angel Morales, Marissa Traina
Advisor committee: Dr. Roy S. Berns (have met with), Prof. Jennifer Kruschwitz, Samuel Steven (have met with)

Contents

Revision History

Rev	Description	Date	Authorization
A	Initial PRD based on customer presentation	10/27/15	MT
B	PRD Version 2 based on new customer meeting	11/1/15	MT
C	PRD Version 3 based on second meeting with customer	11/15/15	MT
D	PRD Version 4 for Final Class Presentation	12/1/15	MT
E	Final PRD Version 5 for Submission	12/10/15	MT

Statement of Advisors

The Multi-spectral Imaging Device project is a senior design driven color accurate image capturing system. As such its design inputs were derived from our interactions with our project advisors, Dr. Roy S. Berns, Prof. Jennifer Kruschwitz, and Samuel Steven.

Team Member Responsibilities

Team Member	**Responsibility**
Joseph DiFabio	• Scribe • Optical Design
Maggie Han	• Project Coordinator • CAD - Mechanical
Angel Morales	• Customer Liaison • Testing & Modeling
Marissa Traina	• Document Handling • Colorimetry

Vision

This product is envisioned as a tripod-mountable camera working with an attached Liquid Crystal Tunable Filter (LCTF) and lens system in order to obtain high-quality, monochromatic images, primarily of painted artwork. A series of these images will be obtained by adjusting the wavelength filter on the LCTF. Having these images will enable us to create a vector in color-space that can be used to capture the true color of various artworks, allowing for improved archival and reprinting abilities. This product is also aiming to be low-cost, and as a result, will seek to utilize already-existing camera models, lens attachments, and LCTFs so that this system can be easily reproducible.

Environment

The system will be designed for use in a lab or studio type environment. The device should be designed for use at approximately 40-100 degrees F, and so that condensing does not occur at any level of humidity on this temperature range. Since this product should be constructed with commercially available components, these standards will be met according to the specifications of these components.

The lighting the customer intends to use with this device is established as common flash bulbs used in photography - customer states that lighting design is beyond the scope of the project.

Regulations and Risk Factors

Due to the primary focus of utilizing commercially available technology (to reduce costs), the resulting product will adhere to the laws and regulations of the components. No alterations will be made which risk the safety of the user or which violate OSHA regulations.

Product Requirement Document

The following details describe the requirements for the end product.

First and foremost, the resulting imaging system should aim to be composed of already-available camera models (ideally, the Canon EOS 5D Mark III, as it is the one Dr. Berns currently uses), lens attachments, and Liquid Crystal Tunable Filters (LCTFs).

The system will aim to eliminate all vignetting from the system. The system, when used with the LCTF, contains some vignetting, thus losing valuable color information in each image captured. A pseudo-telecentric system (in image space) in front of LCTF is being considered to meet this requirement. This setup could also help to limit the incoming angle variations.

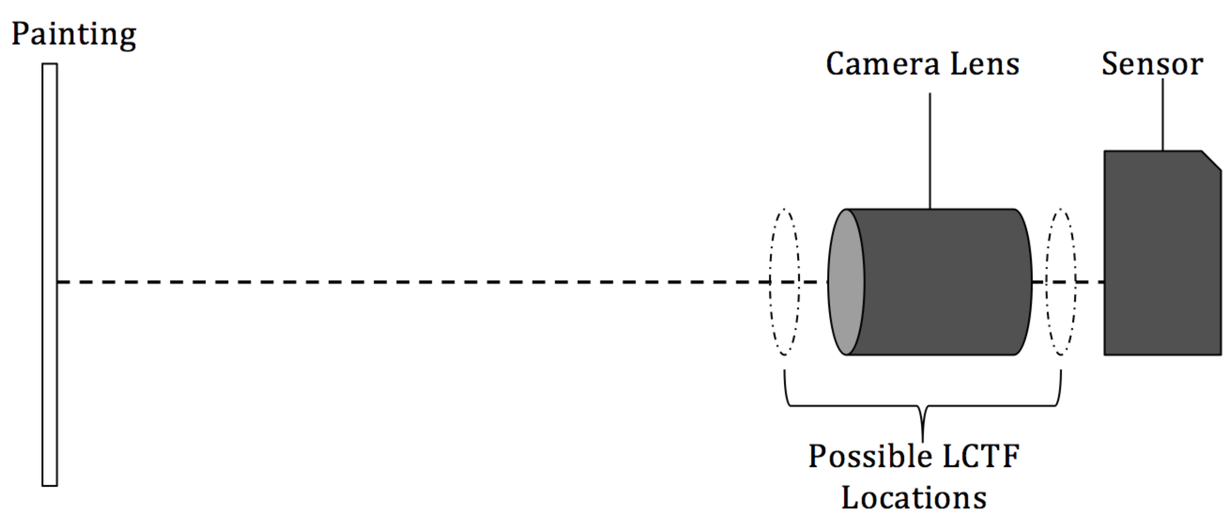
The currently available component is the monochromatic sensor from the Canon EOS 5D Mark III DSLR camera. It has approximately 24.3 megapixel (effective: 22.3 megapixel) with 6.25 um pixel size. The sensor size is approximately 36*24mm.
The target paintings are primarily 24 x 36'' in size (~609.6 x 914.4mm).

Want:
Prototype + documents for customer use. Ideally, documents would instruct a user to assemble a similar system using only commercially available components.

The object distance is approximately 2000mm (object to first surface).

Budget: < $4,000

Rough sketch of system:



Block diagram of system:
**Only responsible for designing LCTF-Lens Coupled Attachment in system*

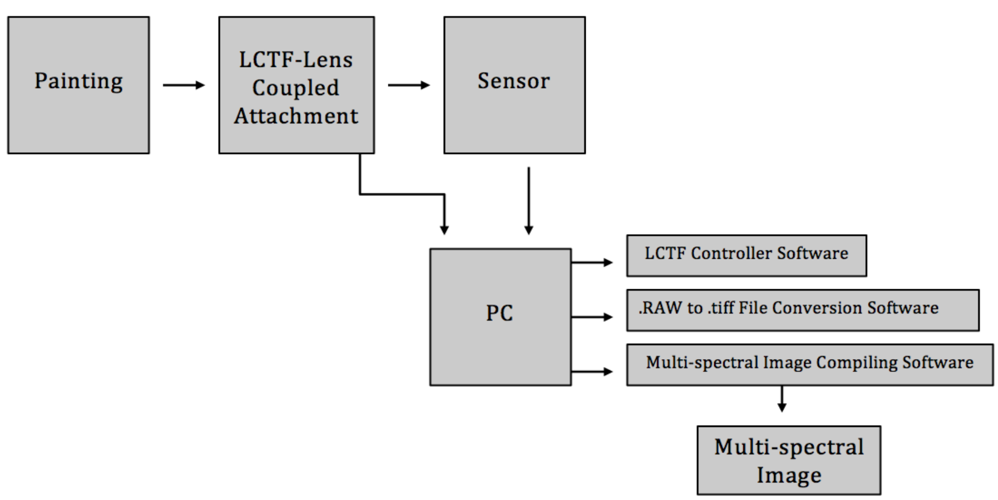


Table of Relevant Specifications		
Specification	**Value**	**Comments**
F/#	≥ 8	Calculated through Etendue
EPD	dependent on EFL	Entrance Pupil Diameter
EFL	85 mm	Capturing the entire painting
	300mm	Meeting the resolution requirement
Wavelength	410-720 nm	Multiple images acquired as LCTF is tuned to pass different wavelengths in this range at 10 nm intervals.
Diagonal Full Field of View	31 degrees	
Resolution	600 pixels per inch (25.4mm)	Stated as "desirable" by customer, in object space
LCTF Thickness	38.1 mm (1.5 in.)	
LCTF Diameter	35 mm	
Working Distance	2 - 5 m	
Angles of Incidence on LCTF	$\leq$ 7.5 degrees	Half angle, Based on angular sensitivity of LCTF
Relative Illumination	$\geq$90%	at outermost edge of 24x36" painting
Sensor Pixel Pitch	6.25 um	Center - to - center

Not Responsible

This design project does not encompass the following:

- Illumination design (Xenon strobes)
- LCTF Controller Software
- .RAW to .tiff File Conversion Software
- Multi-spectral Image Compiling Software

Options for Customer

Due to etendue restrictions, which cannot be avoided, it is not possible to achieve all of the specifications desired for this project. Specifically, the FOV and resolution specifications are at odds, and one or the other must be sacrificed. For this reason, we will present several options. We recommend sacrificing the FOV to achieve the resolution and angular requirements of the project, and to stitch several images (up to 15) together to analyze the entire painting.

1. Updating the sensor and lens:
    a. Upgrade to a Canon EOS 5DS, 50 MP sensor, which contains a smaller pixel size of 4.14 microns - $3599 from Canon
    b. Canon EF-S 18-200mm f/3.5 IS lens set @ 200mm - $699 from Canon
    c. This option achieves the desired resolution at an object distance of 2m. The FOV is 10.35 in.
    d. Note: Bayer pattern must be removed - added cost and unreliable quality

2. Upgrade of just lens - FFL
    a. Canon EF 300mm f/4L IS lens - $1299 from Canon
        i. This achieves the desired resolution at an object distance of 2m. The FOV is 11.06 in.
    b. Canon EF 70-300mm f/4-5.6 IS USM - $649
        i. FOV = 11 in.
    c. Canon EF 75-300mm f/4-5.6 III - $199
        i. FOV = 11 in., less well corrected but might be sufficient

Customer Feedback:

The customer has stated a preference to avoid option 1 listed above, as the added expense of the camera upgrade is not worth the return on performance. He is open to limiting the field of view, however, as stated in option 2. He would like us to investigate making small changes to the system so that the FOV is slightly larger and resolution is sacrificed somewhat. This can be accomplished with the system described, but by simply increasing the object distance. This must be described in detail, along with the effect on resolution, in the documentation provided with the prototype device.

Timeline

Timeline	
By 12/11 (Final PRD Submission)	• Further characterize liquid crystal tunable filter for final first order specs • Meet with Julie Bentley & Samuel Steven to discuss final first order lens design specifications • Present and confirm updated product requirement document with Dr. Berns • Further finalize Spring 2016 Schedule
January	• Create our commercial product wish list • Approve pricing and design options with customer • By end of month purchase most promising design options (2 most promising if the budget can account for it)
February	• Receive products and assemble initial test design • Begin testing setups and determine performance • Finalize mechanical mounting design • Order Mounts
March	• Assemble Final Design • Test Final Design for quality assurance • Create instructional documents for future customer use and ease of reproduction
April	• Cushion time for schedule changes • Present final product to customer

References

"Canon EOS 5D Mark III Specifications." *Canon.com*. Canon. Web. <http://shop.usa.canon.com/shop/en/catalog/eos-5d-mark-iii-body>.

"Verispec Liquid Crystal Tunable Filter Data Sheet." Perkin Elmer. Web. <http://www.perkinelmer.com/CMSResources/Images/44-140156DTS_010053A_01_VariSpec_DTS.pdf>

"Canon EOS 5DS DSLR Camera Specifications." Canon.com. Canon. Web. <http://shop.usa.canon.com/shop/en/catalog/eos-5ds>.

"Canon EF 70-300mm f/4-5.6 IS USM" *Canon.com*. Canon. Web. <https://www.usa.canon.com/internet/portal/us/home/products/details/lenses/ef/telephoto-zoom/ef-70-300mm-f-4-5-6-is-usm/!ut/p/z1/hY_LDoJADEW_hQ9oWgF5LHnEgAGNmOg4G8NiQBKGIYIu-HpH48YYsbv2nqanyJEh78p7U5djo7qy1f2JO-d8l3hJGlHmeUVIQR7TarGzzW1m4vEfwHVMPyogXL-AmX1tYF7zKK-R9-V4gaarFLJWdIMYkIkK2Sha0V_UqGBSSj5n4BJYRFJCBTYswYFmgNsgtS3_vEeF71LgxE7ib0JKU_sLOIS2Bvw4sszV0_kNzLzUSzZlQbVPa8N4AK1mhgk!/dz/d5/L2dBISEvZ0FBIS9nQSEh/>

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