



FEB 21, 2021  
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RE: ENSC 405W/440 Requirements Specification for FlipScan

Dear Dr. Scratchley,

Please find enclosed our detailed requirements specification for FlipScan, a completely automated scanner that will digitize physical books.

This document provides a high level overview of FlipScan, outlining its purpose and requirements. Issues related to sustainability, safety, and engineering standards of our product are also analyzed. Included in the appendix is an acceptance test plan, which we will use when testing the alpha phase release of FlipScan.

The FlipScan team is composed of five passionate members each with different backgrounds: computer engineers Trevor Chow and Kai Sackville-Hii, electronics engineers Abbas Raza and Tom Doherty, and system engineer Aaran Shan.

Thank you in advance for your time spent reviewing our requirements specification document. If you have any questions or concerns please contact our chief communications officer Kai Sackville-Hii by email at [ksackvil@sfu.ca](mailto:ksackvil@sfu.ca) or by phone at +1-778-986-2009.

Sincerely,

Kai Sackville-Hii  
Chief Communications Officer  
FlipScan



# Requirements Specification for FlipScan

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## **Abstract**

FlipScan is a robotic book scanner that automatically flips the pages of books and scans them simultaneously. This document will first introduce the basic purpose of the FlipScan, then outline its functionality by defining the system's software and hardware requirements. The purpose is to provide the reader with proficient understanding of the product and its main components. Included are mechanical, hardware, electrical, and software specific requirements including. Furthermore, this document highlights engineering standards and ensures our product will be able to operate safely and sustainably.

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Glossary

- SBC: Single Board Computer
- GPIO: General Purpose Input Output
- PDF: Portable Document Format

# 1. Introduction

Not everyone has the capability to read a physical book, many people need assistive solutions due to poor eyesight or a lack of motor skills. Audio and digital books are a great solution, however not all physical books have been converted yet. Thus, our research about the subject included reaching out to local libraries to better learn about the implications of scanning books, as well as overall accessibility to disabled users. Through this outreach we were able to find out that the demand for scanning books, and turning them into accessible digital copies, is high due to the large volume of readers with specialized needs. To convert these books into accessible copies librarians go through the tedious task of scanning each page one by one on typical industrial scanners. This task is both time consuming and is highly laboured oriented.

FlipScan, a completely automated book scanner, aims to solve this problem of high demand in audio and PDF books. Flipscan's goal is to efficiently convert physical books into accessible required format, thus reducing the amount of manual labour required by librarians, resulting in people with special needs gaining better access to the books they desire.

## 1.1 Scope

This document will provide the reader with a high-level outline of FlipScan, with specific functional requirements for each development phase. These requirements have been categorized into the subsections general, mechanical, hardware, electrical, and software. Also included are engineering standards which our product must comply with, and the sustainability/safety concerns.

## 1.2 Intended Audience

This document will serve as a functional requirement guideline during the development stages of FlipScan, using it as a measure for the product's progress. This document will also serve for Craig Scratchley, Shervin Jannesar and TAs for grading purposes. Future revision and inquiries will draw from the outlined preliminary framework.

## 1.3 Requirement Classification

Each requirement specification will follow the scheme:

**Req {Section}.{Subsection}.{Requirement Number} {Phase Code}**

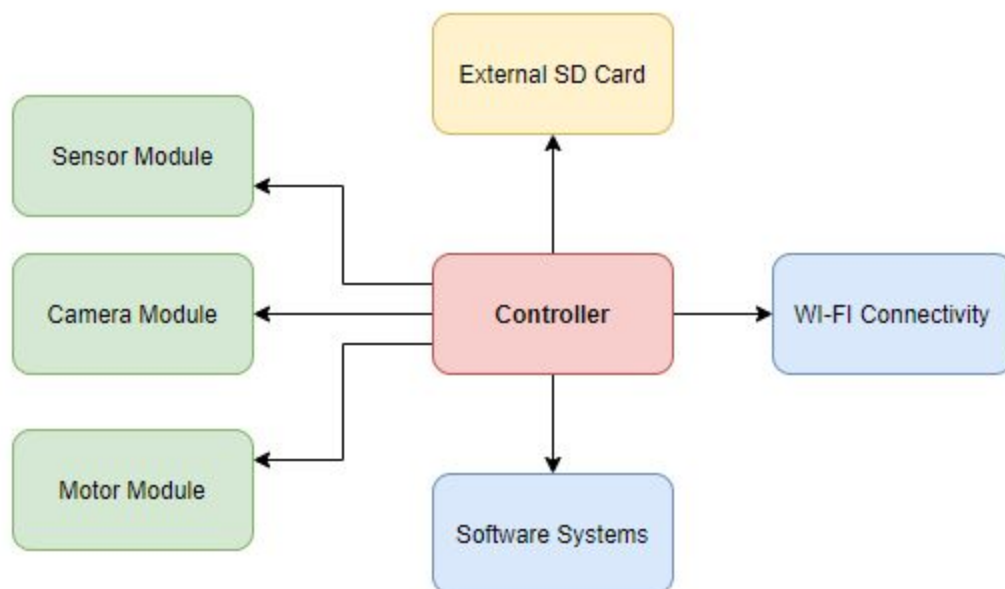
The text inside curly brackets are variables, and will be replaced by the appropriate values. The “section” and “subsection” variable correspond to the requirements location within this document. The “requirement number” variable corresponds to the requirements location within its specific section/subsection. And finally the “phase code” variable corresponds to the phase of development. Table 1.1 specifies the three phases of development.

**Table 1.1:** Product Development Phase Codes

Phase Code	Description
A	Alpha Phase - Proof of concept prototype for end of ENSC 405W.
B	Beta Phase - Engineering prototype for end of ENSC 440.
P	Production Phase - Final product for end users.

## 2. System Overview

FlipScan is a fully automated robotic book scanner that consists of software and hardware components. The hardware is made up of a single board computer (SBC) that connects to the motors, sensors and camera modules. The software controls the SBC, utilizes image processing libraries and controls wifi connectivity. The high-level overview diagram is shown below in Figure 2.1.





**Figure 2.1:** High Level Overview Diagram of FlipScan System

The main process starts when the user interacts with the built in touch interface. They will input their email, number of pages to turn, and then hit the start button to start the scanning loop. Each cycle the camera takes an image, the wheel spins to pinch the page up, then a robotic arm flips the page over. The scanner software uses image processing to enhance the images. It will then generate a PDF and audio file that will be emailed to the address specified by the user. During the alpha phase, the product will only be compatible with a specific size and type of book so as to simplify the requirements. During the beta and production phases, the product will be optimized to work with a wider range of books.

## 2.1 System Requirements

**Table 2.1:** General Systems Requirements

ID	Description
Req 2.1.1 A	The product must flip pages one at a time.
Req 2.1.2 A	The camera shall capture one picture for each page turn.
Req 2.1.3 A	The computer must have sufficient storage for the software, image, and audio file data.
Req 2.1.4 A	The product must email the PDF and audio files to the address defined by the user.
Req 2.1.5 A	The product must be fully automatic.
Req 2.1.6 A	The product must be compatible with a 6"x 9" hardcover book.
Req 2.1.7 A	The product must take an image, rotate the wheel, and rotate the arm in that order for every page.
Req 2.1.8 A	The product must stop scanning once the number of pages to scan, as defined by the user, has been reached.
Req 2.1.9 B	Users must be able to interface with the product using a built-in touch screen.
Req 2.1.10 B	The product must process the raw images.
Req 2.1.11 B	The product must convert the processed images into a PDF and audio file.

Req 2.1.12 B	The product must be compatible with both hardcover and softcover for a 6"x 9" size book.
Req 2.1.13 P	The product must be compatible with both hardcover and softcover books of varying sizes.
Req 2.1.14 P	The product must stop scanning at the end of the book.

## 3. Mechanical Requirements

### 3.1 Page Turner

The page turning mechanism will require multiple moving parts in order to flip a page of a book. The system will use a rubber wheel connected to a motor to spin the wheel 180 degrees to pinch the page up. Then a robotic arm will push the lifted page over to complete the process.

**Table 3.1:** Mechanical Requirements

ID	Description
Req 3.1.1 A	The product must use a rubber roller to effectively lift up the page.
Req 3.1.1 A	The product must use an arm to flip the page.
Req 3.1.2 A	The product must rotate the arm bearing the rubber wheel by 180 degrees.
Req 3.1.3 B	The product must use an air nozzle to separate the pages before flipping.

## 4. Hardware Requirements

There are three key pieces of electronic hardware in the system. The first piece is a single board computer to serve as the controller. SBC's are relatively cheap and easy to program, while having all of the necessary peripherals needed to interface with the other components of the system. A camera will be necessary to photograph the pages of the book. The user interface, a touch screen, will need to connect into the computer, with certain functionality requirements.

## 4.1 Computer

**Table 4.1:** Computer Requirements

ID	Description
Req 4.1.1 A	The SBC must be able to interface with the camera and the page turner.
Req 4.1.2 A	The SBC must be able to handle the load of running the software.
Req 4.1.3 B	The SBC must be able to wirelessly connect to the internet and send data.

## 4.2 Touch screen

**Table 4.2:** Touch Screen Requirements

ID	Description
Req 4.2.1 A	The touch screen must be large enough to accommodate all the options the user can touch.
Req 4.2.2 A	The touch screen must not misread the user's inputs.
Req 4.2.3 A	The touch screen must have enough resolution to ensure the UI text is legible.

## 4.3 Camera

The camera in the system takes the pictures and sends them to the computer. 300 DPI is considered the typical resolution for document scanning, while 600 is considered the highest resolution to use. The camera will be able to scan at least at 300 dpi, with the goal of also being able to scan at 600 dpi.

**Table 4.3:** Camera Requirements

ID	Description
Req 4.3.1 A	The camera must be able to take pictures at 300 DPI or higher.
Req 4.3.2 A	The camera's FOV must be high enough to capture the entire book.

Req 4.3.3 A	The camera must be able to focus on the pages to be scanned.
Req 4.3.4 A	The camera must have an exposure time less than 1 second.
Req 4.3.5 P	The camera should be able to take pictures at 600 dpi

## 5. Electrical Requirements

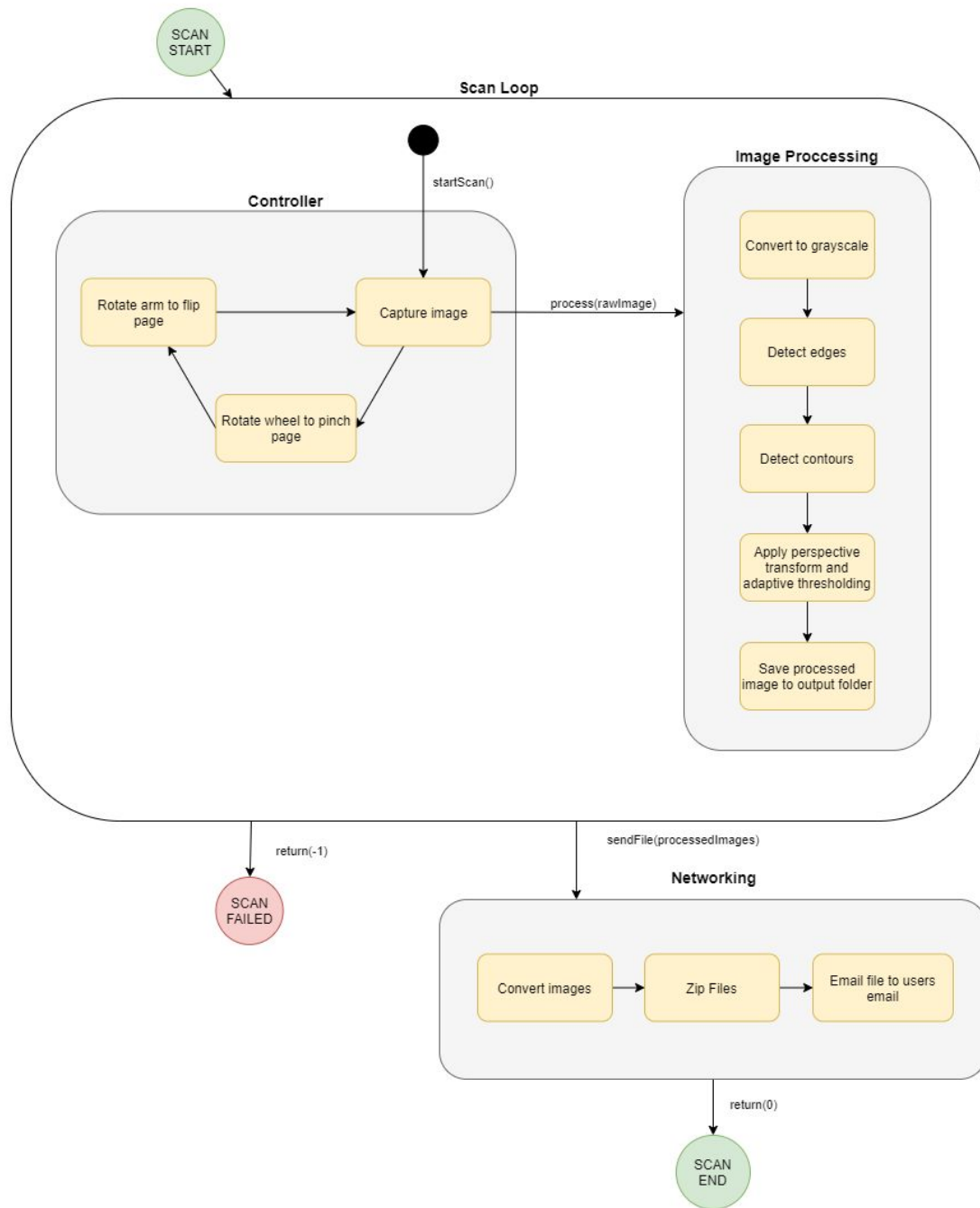
### 5.1 General

**Table 5.1:** Electrical Requirements

ID	Description
Req 5.1.1 A	The power supply must work with a north american wall socket.
Req 5.1.2 A	The power supply must be rated to provide at least 50% more than the maximum power consumption of the system.
Req 5.1.3 A	The power supply must be able to continuously provide power for the duration of scanning a book.

## 6. Software Requirements

FlipScan's software will consist of three main operations, hardware controing, image processing, and networking. Figure 6.1 shows these three operations and their actions as a state diagram. The softwares core loop is the scan loop, in which the hardware controlling and image processing occurs in parallel. Once the scan loop is successfully completed, the files will be converted, compressed, and emailed to an address defined by the user.



**Figure 6.1:** Main program state diagram

## 6.1 General

**Table 6.1:** General Software Requirements

ID	Description
Req 6.1.1 A	The software must be ready to scan on boot.
Req 6.1.2 A	The software must count the number of pages scanned.
Req 6.1.3 A	The software must stop the scanning process once the number of pages to scan, as defined by the user, has been reached.
Req 6.1.4 A	The software must communicate with the hardware modules.
Req 6.1.5 B	If a hardware or software exception is raised, the software must stop the current scan operation, log the error, and reset for the next scan.
Req 6.1.6 B	Any runtime errors must be stored in an error log with a timestamp and callback trace.
Req 6.1.7 B	The software must create a PDF and audio file version of the scanned book.
Req 6.1.8 P	The software must detect when the last page was scanned, exit the main scan loop, and reset for the next scan.

## 6.2 Image Processing

FlipScan's software must make a raw image of a page look like a scanned document. To achieve this, the various tools provided by OpenCV, a robust open source computer vision library [1], should be used. To optimize efficiency, the image processing must run in parallel to the hardware controller. Errors occurred during this processing must not stop the entire scan.

**Table 6.2:** Image Processing Software Requirements

ID	Description
Req 6.2.1 A	The software must process a raw image file into a grayscale top-down perspective transformed image.
Req 6.2.2 B	The software must skip to the next image if processing takes longer than 30 seconds, or an exception occurs.
Req 6.2.3 B	The software must have a success rate of at least 80% when processing raw images.
Req 6.2.4 B	Image processing must run in parallel with the hardware controller process.

## 6.3 User Interface

Users will be able to control the software, and by extension our system, using a built in touch interface. This interface must allow users to start and stop the main scan loop. When a user starts the scan process, our interface must collect an email to send the final processed file to, as well as the number of pages to be scanned. Once a scan is complete, the interface should provide the user with a summary of the scan, identifying any errors that occurred.

**Table 6.3:** User Interface Software Requirements

ID	Description
Req 6.3.1 B	The interface must be accessible once the SBC is turned on.
Req 6.3.2 B	Users must be able to start and stop the scanning cycle from the interfaced.
Req 6.3.3 B	The interface must collect the users email, and number of pages before starting the scan loop.
Req 6.3.4 B	After a successful scan, the touch interface must display a summary including number of pages scan, elapsed time, and any errors messages.

Req 6.3.5 B	If the system fails due to a hardware or software exception, the interface must display an error message.
Req 6.3.6 B	The user must be able to define the name of the output files.

## 6.4 Networking

Once the scan is completed, and the raw images have been processed, the system must send the compressed files to the email address defined by the user. Sending these files via email is preferred by FlipScan's users, since it is already integrated into their workflow.

**Table 6.4:** Networking Software Requirements

ID	Description
Req 6.4.1 A	The software must send the compressed files to the email address defined by the user.
Req 6.4.2 B	If the email fails to send, the software must display an error message and allow users to retry.
Req 6.4.3 P	If the SBC is not connected to the network, the software must store the files and email it once connected again.

## 7. Sustainability & Safety

There are multiple issues that need to be addressed throughout the designing process. This analysis hopefully covers the "cradle-to-cradle" cycle for the product. The system needs to be safe and reliable enough to not inflict any harm to the user or the item being scanned. Following are some risks that are involved during the operation of this device.

### 7.1 General

**Table 7.1:** Sustainability & Safety Requirements

ID	Description
Req 7.1.1 A	The book must not be damaged or bent during the scanning and flipping process.
Req 7.1.3 A	To ensure safety of the user, the flipping mechanism must only start after the confirmation from the user.



Req 7.1.4 B	Making sure to not send the documents to wrong email address or cloud drive
Req 7.1.5 P	The power supply should be >80% efficient
Req 7.1.6 P	The system should contain >70% recyclable materials
Req 7.1.7 P	The system should be expected to work for at least 5 years before failing

## 8. Engineering Standards

### 8.1 Safety & Legal

**Table 8.1:** Safety & Legal Requirements

ID	Description
Req 8.1.1 A	The system must comply with CSA-C22.2 NO. 61508-1:17 [2]
Req 8.1.2 A	The emergency stop must comply with ISO 13850:2015 [3]
Req 8.1.3 P	The system must adhere to ICES-003 [4]

### 8.2 Environmental

**Table 8.2:** Environmental Standards Requirements

ID	Description
Req 8.2.1 A	ISO 14040:2006 [5] will be used to assess the life cycle of the product

### 8.3 Electrical

**Table 8.3:** Electrical Standards Requirements

ID	Description
Req 8.3.1 A	Any circuit diagrams should follow IEEE standard 315 [6]
Req 8.3.3 A	The power supply must comply with CSA C22.2 No. 223-15 [7]
Req 8.3.5 A	The system must comply with CSA-C22.2 NO. 0:20 [8]

## 8.4 Software

**Table 8.4:** Software Standards Requirements

ID	Description
Req 8.4.1 A	The software for transmitting the data must comply with ISO/IEC TR 23188:2020 [9]

## 9. Conclusion

FlipScans goal is to efficiently digitize books through an automated page turning process. This document illustrates a high level overview for the FlipScan product, and elaborates on the functional requirements for alpha, beta, and production phases of the product. Engineering standards, sustainability, and safety issues are also addressed throughout this document. The main product requirements for FlipScan are summarized as follows.

Process of book scanning will start with the user placing the book in the middle of the device and initializing the process by using the touchpad interface provided with the device. FlipScan will be required to lift the pages one by one by using a rubber roller wheel and air nozzle making sure pages do not stick. Meanwhile, the rotating arm will lift the page and turn it by 180 degrees to ensure complete turning of the page for the next scan.

Next step required by FlipScan will be to take pictures of every page of the book. It will be required by FlipScan to stop at the last page as a stopping condition to come out of the loop of scanning process.

Third requirement will be software based where pictures taken by the camera will be processed by using image processing algorithms for optimal image conversion around the bends of the book. Hardware required for the software and networking processing will include SBC which will act as a processing unit for the entire FlipScan scanning process.

## 10. References

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## Appendix: Acceptance Test Plan

This section defines the conditions and criteria for an acceptable alpha phase demo at the end of 405W. Included in our acceptance test plan are test cases and the conditions upon which to hold these tests. These test cases are based on FlipScan's requirement specifications, and will be passed or fail.

Testing the alpha phase of FlipScan is intended to prove our concept of flipping and scanning a book. It will therefore not be as robust in this phase as it would be in the beta and production phase. The test conditions outlined below provide a controlled environment for us to efficiently test the product. Table A.1 provides detailed test cases to be used during alpha phase testing.

### Test Conditions:

- The tests must be held in a well lit room, with a strong wireless network connection, and at least one power socket available.
- The system must be set on a flat surface.
- The SBC must be connected to power, WiFi, the camera module, the arm module, and the wheel module.
- The book to scan should be hard cover, with dimensions around 6" by 9" and approximately 500 pages.
- The pages of the book should stay open on the surface with gravity.

**Table A.1:** Acceptance Test Cases

ID	Acceptance Criteria	Pass / Fail	Comments
T1	The product flips pages one at a time.		
T2	The camera captures one picture for each page turn.		
T3	The computer has sufficient storage for the software, image, and audio file data.		
T4	The product stops scanning once the number of pages to scan, as defined by the user, has been reached.		
T5	The software processes a raw image file into a grayscale top-down perspective transformed image.		

T6	The product emails the PDF and audio files to the address defined by the user.		
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