A Simplified Design for the *C. elegans* lifespan machine

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File S2 – SOP for V700 + Box Fan Lifespan Machine

General information: This standard operating procedure outlines an alternate method for the modification of V700 Automated Lifespan Machine (ALM) scanners. This method involves cutting large holes in the scanner chassis and transparency unit (TPU), and utilizing box fans for air circulation instead of CPU fans directly attached to the scanner.

Alternate Epson V700 modification method: Most aspects of our Lifespan Machine design are identical to those previously described (Stroustrup *et al.* 2013), with the major exceptions being structural modifications made to the image acquisition scanners, and the scanners' location in a temperature-controlled room as opposed to an incubator. No changes to any of the associated software or to the computers used are necessary.

Epson V700 scanners were modified by cutting four holes into the sides of the bottom main scanner chassis and the top TPU. First, the screws attaching the scanner bed to the bottom unit were removed, and tape was placed over the slit aperture of the scanning arm. The arm was then gently pushed up to the back end of the scanner to protect it from shavings created by the cutting process.

Holes cut into the main unit were 2" in height and located about 0.75" below the top scanner bed surface. Holes cut into the TPU were 1.5" in height and located at the top of the unit. The locations of the holes are shown in Figure 1A and Figure 2B. A sufficiently powered Dremel tool [Dewalt DW 660] is able to cut through the sides of the scanners. All holes were first cut out onto cardboard templates to ensure consistency between scanners. The tape over the aperture slit was removed, the plastic shavings were vacuumed out of the scanner interior and the scanner bed was replaced. The scanners were then adjusted to ensure a proper focal plane as previously described (Stroustrup *et al.* 2013).

Shelving racks were assembled using metal bars and shelves. A total height of 7' and 10" spacing between shelves allows for 6 scanners to be placed in one rack with adequate room beneath the scanners to allow air circulation and between the scanners to fit the box fans (Figure 1B). Cutout holes in the rack supports allow for USB hubs, scanner power adapters, USB and power cables, and other necessary equipment to be easily attached with zip ties to the shelves, reducing clutter and potential heat buildup from messy wiring. Box fans (Lasko 3733) were attached to the right side of the shelves using zip ties, blowing to the left towards the scanners. Air filters (Honeywell MERV 11, 20"x20"x1") were then affixed using zip ties onto the intake side of the fans.
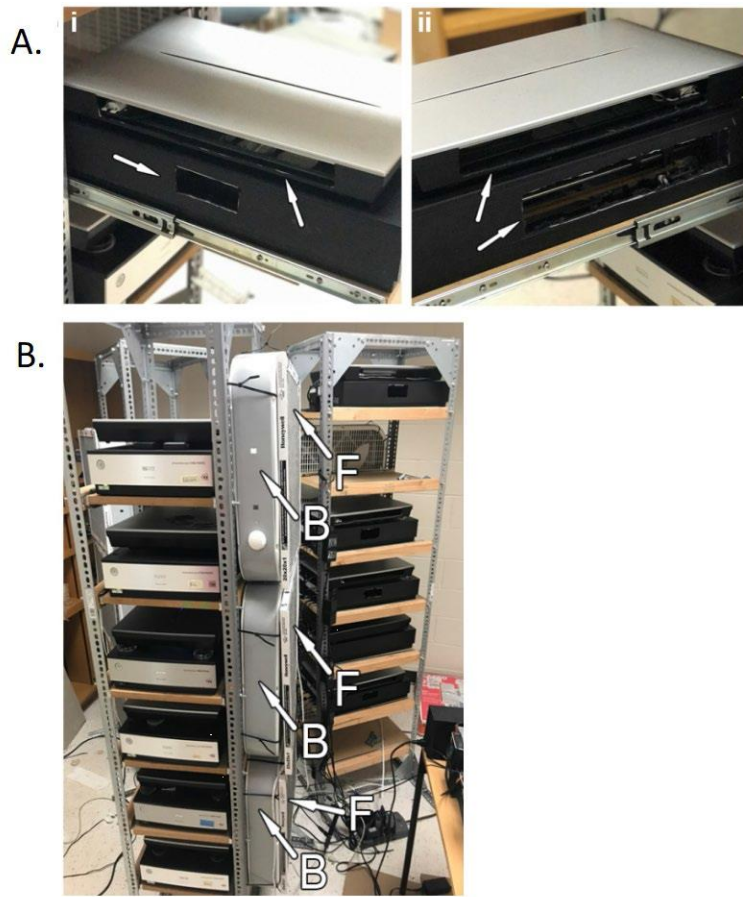
Figure 1: Alternate V700 Lifespan Machine design and room set-up. A) Alternate V700 Lifespan Machine modifications, with two cutouts (arrows) in the left side (i) and right side (ii). Room set-up and V700 Lifespan Machine array for the alternate design. Scanners are arranged on vertical racks with drawer slides for easy loading. Each box fan (B) covers two scanners, and has an attached filter (F) to remove particulates from the airflow.
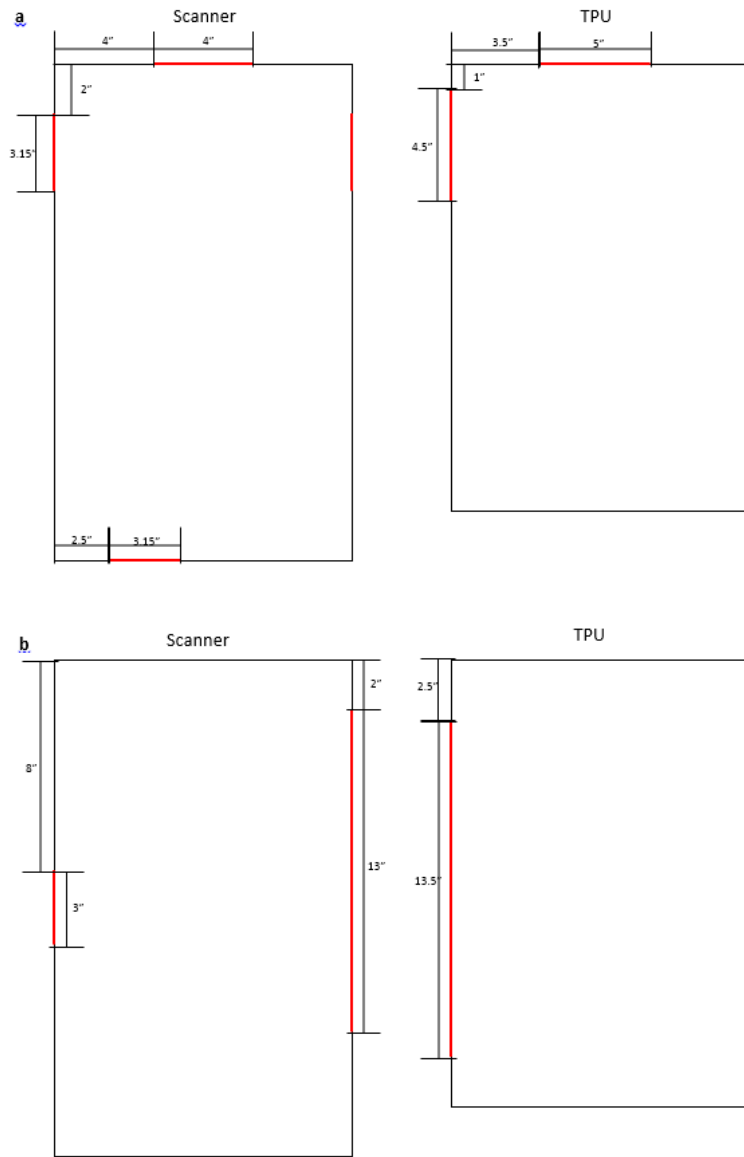
Figure 2: Differences between the number, location, and size of holes cut out of modified Epson V700 scanners in the original Lifespan Machine design (a, (Stroustrup *et al.* 2013)) and our alternate design (b). Locations of the cuts are shown in red.

Literature Cited

Stroustrup N., B. E. Ulmschneider, Z. M. Nash, I. F. López-Moyado, J. Apfeld, *et al.*, 2013 The *Caenorhabditis elegans* Lifespan Machine. Nat. Methods 10: 665–70. https://doi.org/10.1038/nmeth.2475

File S3 - Code for electromagnetic field measurements

```python
"""
This program samples and stores max waveform amplitude data from a
Siglent
SDS1202X-E oscilloscope connected to a Raspberry Pi 4 4GB via USB for the
purpose of characterising the EMF emitted by Epson v700/v800 document
scanners used in the Phillips Lab at the University of Oregon for
Automated
Lifespan Machine C. elegans research.

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Organization: Phillips Lab, University of Oregon
Version: v1
"""
import csv import
visa import
math import
time import
datetime import
subprocess


# SETTINGS
# Time (in seconds) that will elapse between samples
sample_period = 0.25
# How many extra samples will be taken after scan finishes
extra_samples = 25
# Number of replicate experiments to do
num_replicates = 3
# Name of data file for each replicate in the format:
# <scanner_name>_<scanner_type>_<columnrow>_<replicate_number>
file_name = 'RogerYoung_v700_D3_R{}.csv'
# Directory in which to store data files with scanner name and type
specified
file_dir = '/home/pi/Desktop/rogeryoung_v700_emf_data/'


# FUNCTIONS
def get_scope_max(scope):
  """
  Samples max amplitude value of waveform
  measured by oscilloscope
  Args:
    scope: The oscilloscope object created using the
    resources.open_resource() function from the
    pyvisa library
  Returns:
    The max amplitude of the waveform recorded by the
    oscilloscope
  """
  # Get full string reading from oscilloscope
  full_reading = scope.query('C1:PAVA? MAX')
  # Parse section of string that contains max amplitude
  # in the form '0.00E+00V'
  reading = full_reading.splitlines()[0].split(',')[1]
```

```python
    # Get significand of max amplitude string
    significand = float(reading[0:4])
    # Get magnitude of max amplitude string
    magnitude = float(reading[6:8])
    # Convert from scientific notation to decimal
    if reading[5] == '+':
        value = significand * math.pow(10, magnitude)
    else:
        value = significand * math.pow(10, magnitude * (-1))

    return value


# SETUP
# Do initial scan and measure how long it takes
now = time.time()
p = subprocess.Popen(['./scan.sh'], stdout=subprocess.PIPE)
print("Starting duration measurement scan")
p.wait()
scan_time = time.time() - now
print("Scan duration is {} seconds".format(scan_time))

# Set data logging time approximately equal to how long scan takes
run_time = int(scan_time)
print("Data collection time is {} seconds".format(run_time))

# Calculate number of total samples given runtime and sample_period
num_samples = int(run_time / sample_period)

# Setup resource manager
resources = visa.ResourceManager('@py')

# Find available instruments resources_list
= resources.list_resources()
print(resources_list)

# Connect to oscilloscope
oscilloscope = resources.open_resource(resources_list[1])

# Check oscilloscope response
print(oscilloscope.query('*IDN?'))


# MAIN
# Do initial sample to overcome first AssertionError
try:
  get_scope_max(oscilloscope)
except AssertionError:
  time.sleep(1)
  pass

# Calculate time required to sample and process max value
now = time.time()
max_val = get_scope_max(oscilloscope)
```

```python
sample_time = time.time() - now
print("Scope sample time is {} seconds".format(sample_time))

# Set the pause time between samples
wait_time = sample_period - sample_time

# Wait 5 seconds for scan bar to get back to beginning and fully
# reset before starting data collection runs
time.sleep(5)

for r in range(num_replicates):
  # Start data collection scan
  p = subprocess.Popen(['./scan.sh'], stdout=subprocess.PIPE)
  print("Starting data collection scan for replicate {}".format(r))

  # Name of data file
  replicate_file_name = file_name.format(r + 1)
  # Full string of data file for storage at end of script
  data_file_str = file_dir + replicate_file_name

  with open(data_file_str, "w") as data_file:
    data_file_writer = csv.writer(data_file, delimiter=',',
                        quoting=csv.QUOTE_MINIMAL)

    for i in range(num_samples + extra_samples):
      # Get the current time
      now = str(datetime.datetime.now())[11:22]
      # Get the max amplitude of the waveform
      max_val = get_scope_max(oscilloscope)
      # Write the max amplitude to the data file
      data_file_writer.writerow([now, max_val])
      # Wait until it's time for the next sample
      time.sleep(wait_time)

    # Wait 5 seconds for scan bar to fully reset before starting next
scan
    time.sleep(5)

    print("Sampling for replicate {} has ended".format(r))

# Close scope to free it up
oscilloscope.close()
print("Scope closed")
```

File S4 – SOP for V800 + Box Fan Lifespan Machine

General information: This standard operating procedure outlines a method for implementing V800 Automated Lifespan Machine (ALM) scanners with essentially no modification.

Alternate Epson V800 implementation method: While the V800 scanner still has a slight thermal gradient from the front to the rear of the device; the heat generated can be managed without creating any cutouts at all in the chassis. A single box fan with an attached air filter is sufficient to eliminate this gradient and help to ensure that the microenvironment across the scanner bed is consistent (see room set-up in Supplemental File 2: V700 + Box Fan Lifespan Machine).

Another important change in the V800 is that the optics are also slightly improved, such that the need for the lens adjustment step during construction may be eliminated if plates are placed directly on the scan bed without a glass plate. If focal plane adjustment is required, follow the previous published methods ((Stroustrup *et al.* 2013) and see nota bene in Supplemental File 2: V700 + Box Fan Lifespan Machine).

Figure 1: V800 Lifespan Machine design and room set-up at Rutgers.

Literature Cited

Stroustrup N., B. E. Ulmschneider, Z. M. Nash, I. F. López-Moyado, J. Apfeld, *et al.*, 2013 The *Caenorhabditis elegans* Lifespan Machine. Nat. Methods 10: 665–70. https://doi.org/10.1038/nmeth.2475
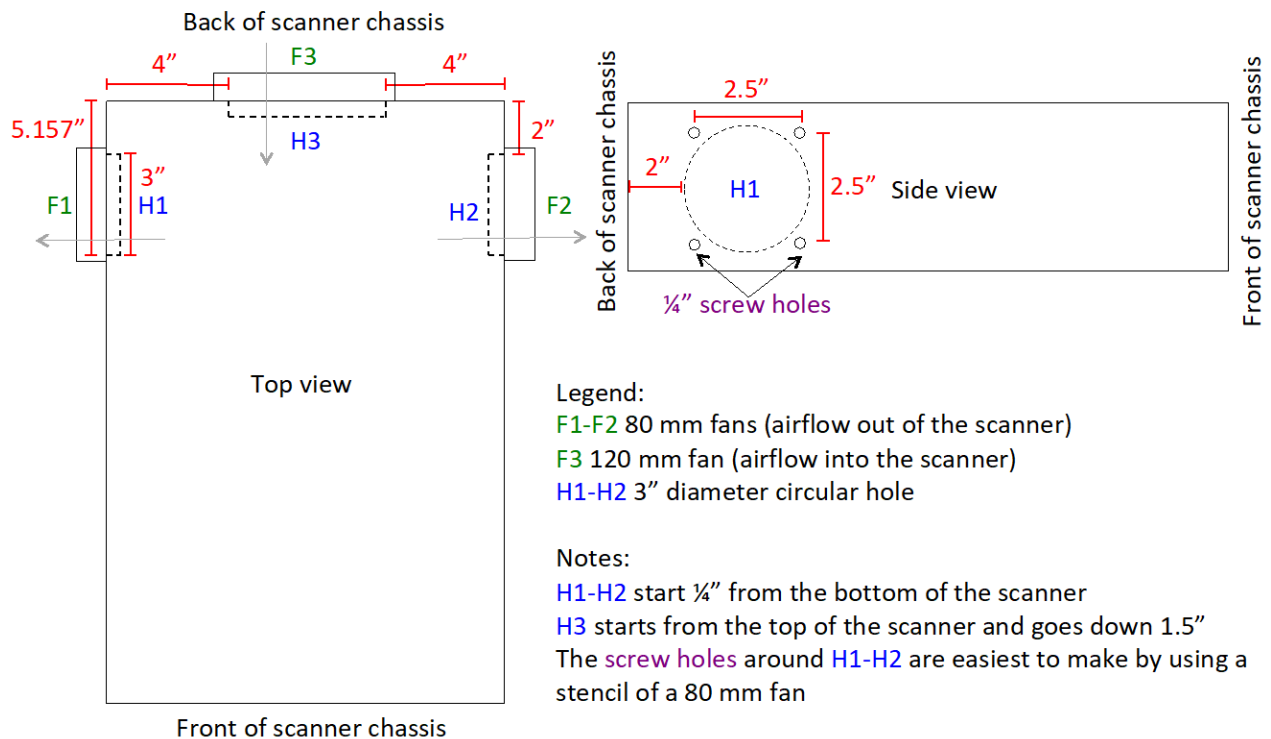
File S5 – SOP for Modified V800 Lifespan Machine

Modified V800 LED Scanner Lifespan Machine (Oregon)

General information: This standard operating procedure outlines one method for modification of V800 Automated Lifespan Machine (ALM) scanners. The LED scan bar on the V800 scanner generates less heat than the previous version of this scanner, the V700, and thus requires less venting to equilibrate temperatures on the scan bed to ambient temperature in the room. Modification is a simplified version based on the original Lifespan Machine methods (Stroustrup *et al.* 2013) with the following changes:

- No modifications to the transparency unit (TPU)
- Holes cut in the scanner/fans reduced to three (see diagram)
    - One hole in the back of the scanner chassis, two holes on the back sides of the chassis
- Side holes cut using a drill with a 3 inch hole saw drill bit
- Side fans attached with screws instead of hot glue
    - Four corner holes are drilled with a 1/8 inch drill bit and 80 mm fans are attached with 1 ½ inch 4-40 threaded screws and wing nuts
- Back fan hung with nylon string and secured to the TPU with Gaffer's tape instead of a screw in the TPU

V800 chassis modification:

Legend:
F1-F2 80 mm fans (airflow out of the scanner)
F3 120 mm fan (airflow into the scanner)
H1-H2 3" diameter circular hole

Notes:
H1-H2 start ¼" from the bottom of the scanner
H3 starts from the top of the scanner and goes down 1.5"
The screw holes around H1-H2 are easiest to make by using a stencil of a 80 mm fan

Modified V800 LED Scanner Lifespan Machine (Oregon)

Epson V800 modified for lifespan experiments:

Nota bene: Once the scanners have been modified, it is important to adjust the focal plane such that the worms on a plate are in focus (Stroustrup *et al.* 2013). Previous protocols for the V700s involved accessing the lens from both the bottom and top of the scan bar, however V800s have a metal plate blocking access from the top. All adjustments can be made from the bottom of the scan bar. The V800s use a dual lens system with two lenses within the scan bar, so it is important to adjust the focus of the correct lens. Using the Epson scan software, set the document type as Film (With Film Area Guide) and take a preview scan to move the correct lens into an accessible position for adjustments.

Literature Cited

Stroustrup N., B. E. Ulmschneider, Z. M. Nash, I. F. López-Moyado, J. Apfeld, *et al.*, 2013 The *Caenorhabditis elegans* Lifespan Machine. Nat. Methods 10: 665–70. https://doi.org/10.1038/nmeth.2475

Figure S1 - Schematic of custom designed plate holder
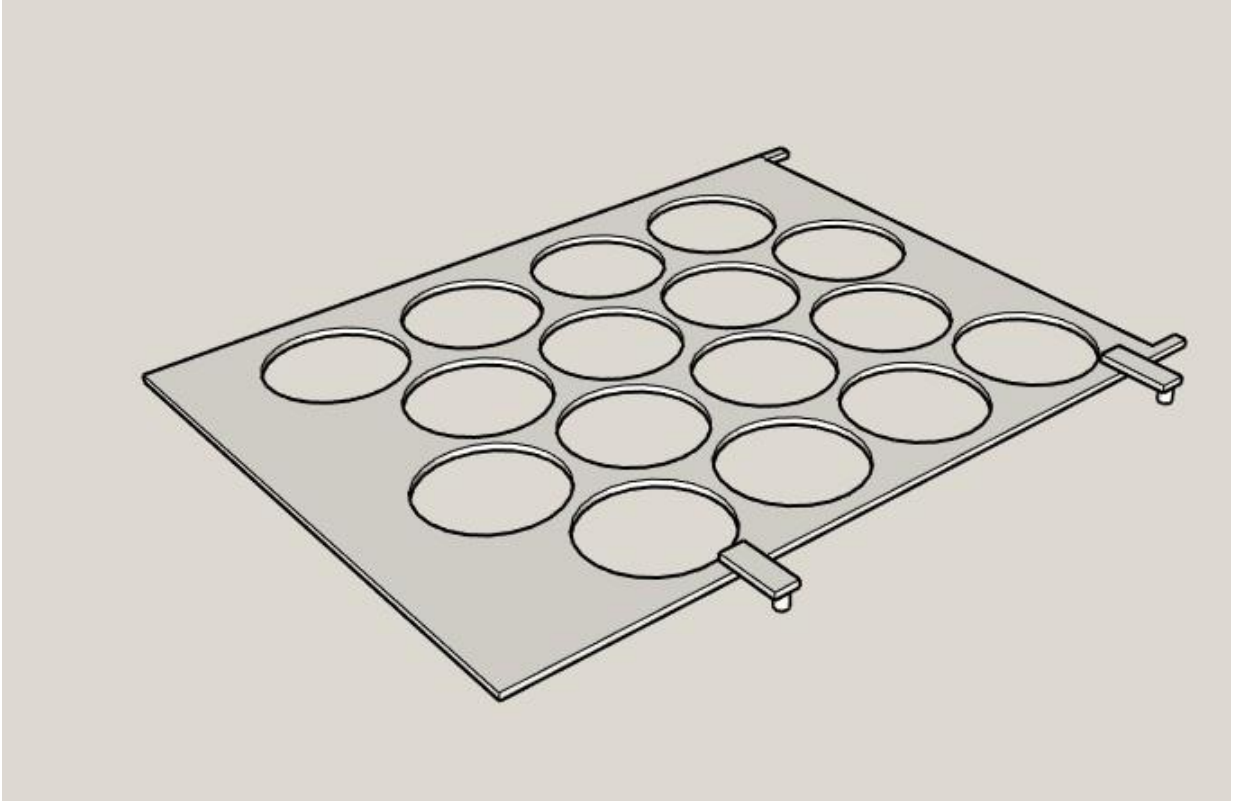
Figure S1. Schematic of custom designed plate holder, which anchors plates over the scanner bed. The locking tabs on the side of the holder keep plates in a static position run to run. Plate holders are now commercially available from Xiamen Ruicheng Industrial Design Co, Ltd. (https://chinaruicheng.en.alibaba.com/)

Figure S2 V700 vs V800 light output
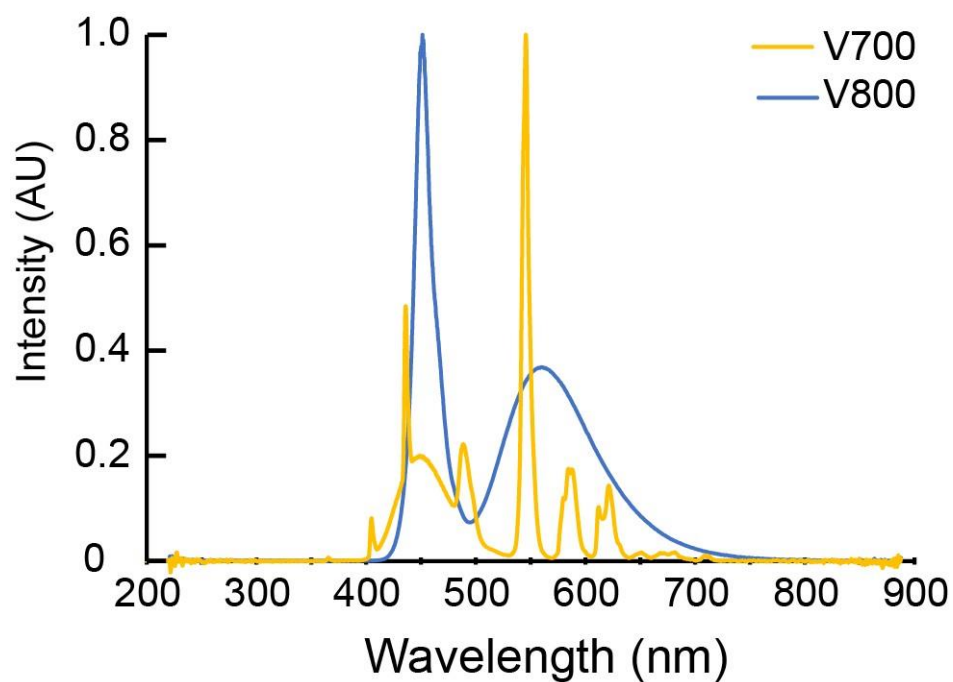
Figure S2. V700 vs. V800 light output. Representative measurements of light intensity for V700 and V800 scanners show negligible emissions in wavelengths shorter than the visible range.