Optimization, Validation, and Implementation of a UV Disinfection Method for N95 Face Masks

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This document summarizes an ultra-violet light disinfection method for N95 face masks developed at the University of Chicago using a commercial room disinfection system. Procedures for mask handling and disinfection are appended after the summary. The system geometry, validation procedures, and data from validation measurements are documented in the attached slide deck. Slide numbers in the text that follows refer to that slide deck.

The COVID-19 pandemic and attendant scarcity of medical personal protective equipment (PPE) have inspired institutions to pursue strategies for reusing and extending the lives of items intended for single use such as N95 masks[1, 2]. Foreseeing the possibility of such shortages during a pandemic, several investigators have explored possible mask disinfection protocols in recent years[3-5]. In a report to the U.S. Food and Drug Administration, Heimbuch and Harnish examined the effectiveness of ultra-violet germidical irradiation (UVGI) for disinfecting N95 masks inoculated with H1N1 influenza virus[6]. They determined that a dose of 1 J/cm^2 resulted in a 3-4 $\log_{10}$ reduction of initial viral load, with final concentrations of viable virus below detection limits. They further determined that masks could be disinfected more than a dozen times without loss of filtration efficiency or reduction in material strength.

The University of Chicago Medical Center (UCMC) owns three Surfacide Helios UVGI systems designed and utilized for whole room disinfection. Each system consists of three emitters, and each emitter contains three low pressure mercury vapor lamps, 1.2 m long, with a specified irradiance of 450 $\mu W/cm^2$ at 1m each. The three lamps, with their long axes vertical, are arranged in a 1" equilateral triangle and housed in a portable tower. The lamps have a peak emittance in UV-C radiation at 254 nm wavelength. Behind the lamps is a nominally parabolic reflector that directs UV radiation forward into a full width at half maximum fan of 60˚ (slides 2-3). The three emitters of a complete system work in concert to disinfect the surfaces of a room by means of motorized rotational sweeps that are synchronized and guaranteed to overlap by the use of laser targeting (slides 6-8,18).

Although the Helios system was designed and marketed for room disinfection, because of a shortfall in N95 mask availability during the COVID-19 pandemic, Surfacide engineers rapidly developed and published a protocol for mask disinfection[7]. It calls for constructing a PVC frame to support masks in a planar array and positioning the three Helios emitters in a line parallel to the plane of the frame and 1.2 m away. Surfacide engineers mounted a UV sensor with its face in the plane of the frame, and measured doses at several locations. Based on these measurements, they recommend an exposure time of 30 minutes per side of the frame (to irradiate the front and back surfaces of the masks) in order to exceed 1 J/cm^2. We commend the team at Surfacide for their rapid response to a quickly evolving public health crisis, for sharing their measurement data, and for publishing their protocol.

We have conducted further measurements at UCMC in an effort to optimize mask and emitter geometry, maximize throughput, and verify that the curved surfaces of the masks, both inside and out, will receive sufficient UV-C dose for disinfection. Importantly, the latter requires measurements with a UV sensor mounted in several orientations in addition to placing the sensor face in the plane of the mask support frame. Like Surfacide, we have adopted the 1 J/cm^2 of Heimbuch and Harnish[6] as our minimum required UV-C radiation dose.

The UCMC mask disinfection system uses a copper frame to support a 4 x 8 array of N95 masks. Copper was selected because plastics can experience embrittlement or failure following prolonged exposure to UV light. Screws are attached with 2" spacing on vertical frame members so that masks can be mounted in a chevron pattern that allows close packing while ensuring the elastic bands to not touch or overlap (slide 16). Masks are gently stretched open to prevent shadowing. The emitters are arranged in a wide V-shape, rather than a line, with those at the ends angled inward 45˚ to ensure illumination of the outer faces of masks at the horizontal edges of the frame while minimizing unused light spilling beyond the ends of the frame. The center emitter is 30" from the mask support frame (slide 17).

An International Light Technologies Model ILT770-NB spectrophotometer was used to measure UV-C dose delivered to multiple locations throughout the frame (slide 5). Measurements near the center of the frame in both the horizontal and vertical dimensions were made with the face of the sensor in the plane of the frame. Additional measurements in the upper right and lower left corners were conducted with the face of the sensor angled 45˚ up, down, left, and right in order to evaluate dose delivered to the curved surfaces of the masks in the regions of the frame likely to receive the least light. Data were recorded as both instantaneous dose every four seconds, and integrated dose over 9-12 minutes.

As expected, the doses received at the corners of the frame are lower than those near the center (slide 11). Doses with the sensor angled upward (in the upper right corner) or downward (in the lower left corner) were lower than those measured in the same locations with the sensor face in the plane of the frame. Lower still were doses measured with the sensor angled to the left (in the upper right corner) and to the right (in the lower left corner) (slides 12, 14). This is because the latter orientations receive only grazing illumination from their nearby right and left emitters, respectively, and weak illumination from the more distant center emitter (slides 17-18).

The emitters sweep their radiation fans from side to side between two wall-mounted laser targets (slides 6-8,18). The positions of these targets, and the total exposure time needed, were optimized with the sensor positioned above the top of the frame and angled toward the center – i.e., in an extreme position and the weakest orientation. Based on these measurements, we selected a 48” spacing (24” to centerline) between targets mounted on a wall 23” behind the mask frame. The required 1 J/cm^2 was achieved in 11 minutes at this weakly illuminated location and orientation outside the frame. We have therefore chosen a 12-minute exposure time per side.

We have assembled 5 frames so that while one is exposed to UVGI, others can be loaded and unloaded in an adjacent room. Prior to each exposure, personnel verify that the emitters and the frame are in their designated positions using alignment marks on the floor. During each exposure, the sensor is mounted in the lower left corner, with its face angled to the right (the weakest location/orientation within the frame) in order to verify a dose that is > 1 J/cm^2 and that is consistent with previous measurements as a secondary check that the emitters and frame are in their correct positions. In our experience, with 12 minutes of exposure per side, plus time to roll frames in and out of the room and rotate 180˚ between sides, a cycle time of 30 minutes per frame is readily achieved.

We have validated and are currently reprocessing 5 mask models, all of which have smooth surfaces inside and out that are readily accessible to UV light:

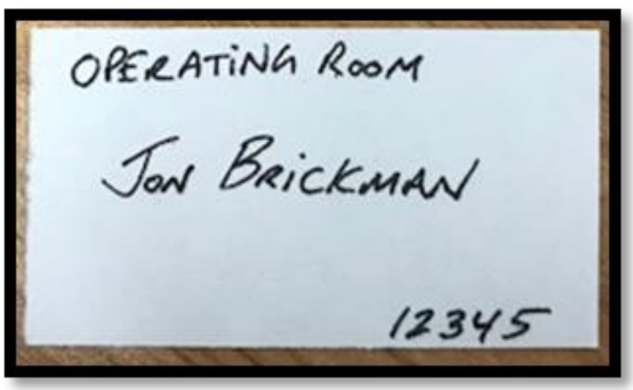
- 3M 1860
- 3M 1870
- 3M 8210
- Kimberly Clark PFR
- Sperian W1400

Since each frame holds 32 masks and two frames can be disinfected per hour, a throughput of 1536 masks per day is possible with personnel working in shifts. UCMC owns three Helios systems. At present, one is dedicated to mask disinfection. The remaining two are in use for their intended room disinfection capabilities, but if needed a second system can be made available for mask disinfection on a temporary basis, doubling throughput.

The following text outlines the procedures for reprocessing the above masks. Only non-COVID exposed masks are reprocessed. Any mask used in COVID units, on COVID patients or on PUI cases are discarded and not taken for reprocessing.

PROCEDURE FOR N95 MASK USE, COLLECTION AND PREPARATION FOR DISINFECTION

1. Only wear an N95 MODEL and SIZE for which you have been appropriately fit tested.
2. Don appropriate PPE based on the type of patient care activity you will be performing.
3. If you are going to be performing an aerosolizing procedure (e.g. intubation/extubation, NIPPV, chest tube, etc.) wear a disposable procedure mask or face shield over your N95 to protect it from large droplet soiling.
4. Once your patient care activity is complete, sanitize your outer gloves and remove your gown and outer pair of gloves immediately prior to leaving care area.
5. Proceed to the drop-off location. Sanitizer should again be used to clean your remaining pair of gloves.
6. Get one 1" x 2" index card and label it with your unit, full name (or first initial and last name), and five digit employee ID.

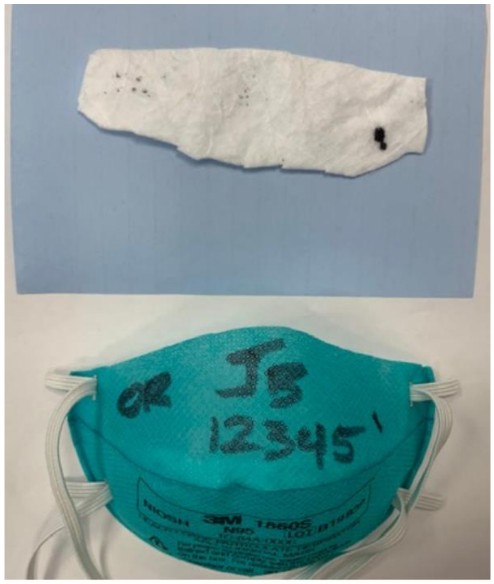


7. Remove your N95 per CDC Guidelines
    1. DO NOT touch the front of the N95.
    2. First, tilt your head forward.
    3. Use two hands to grab the bottom strap, pull to the sides, then over your head.
    4. Use both hands to grab the upper strap, pull to the sides, then over your head.
    5. Keep tension on the upper strap as you remove it, which will let the mask fall forward.

8. Inspect your N95 mask for signs of damage (see below); if noted dispose of the N95 immediately.
    1. Tears or rips in mask
    2. Nose bridge (metal and/or foam) not intact
    3. Soiled/dirty (e.g., make-up, etc.)
    4. Head bands not secured
    5. Alterations (e.g., tied or knotted band(s))

6. Discoloration on N95 and/or band (e.g. written information or markings made with marker, ink pen, etc.)

    Never write on mask because markings may bleed through material. See the photo below of a cross section cut from a mask with information written on the surface.

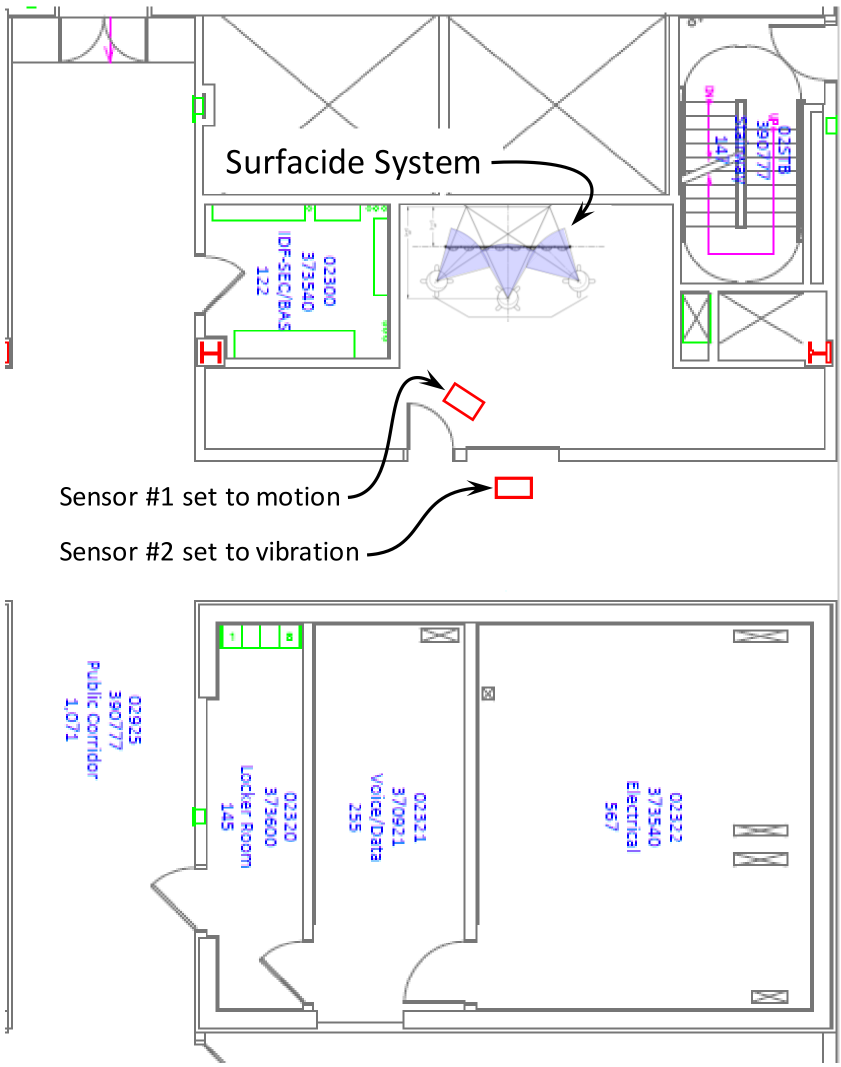


9. Place one N95 and one completed index card into a paper bag.
10. Close brown bag and staple
    1. Note: A completed index card must be present inside the bag with one N95.
    2. Labeling the exterior of the bag instead of card inside will result in mask being discarded
11. Place your bag in the collection receptacle
12. IMPORTANT - Please note the following reasons for rejected N95s
    1. ANY changes to its physical appearance
    2. INCOMPLETE index card
    3. MISSING index card
    4. Index card with > 3-hole punches
    5. ONE card sent with MULTIPLE masks
    6. Information WRITTEN on bag in lieu of SENDING A COMPLETED index card
    7. N95 mask is not hospital issued (e.g. Home Depot brands N95, etc.)

UVGI UNIT SETUP AND CALIBRATION

<u>These instructions include the setup and calibration of the Surfacide Emitters. UV Tech will only need to perform emitter calibration one time for every 3 loads if run back to back.</u>

1. Set the motion sensors in the two designated locations inside and outside of the processing room.



2. Sensors should be turned on (bottom slide), lights will flash on the sensor.
3. Sensor #1 should be set to motion (remains in room).
4. Sensor #2 should be set to vibrate (moved outside of room to outlined space on floor).
5. Make sure sensor lights are aligned and face each other. Lights will show green when aligned.

MOTION

VIBRATE

Tap search and enter 02. Select the room "02325".

Press the "NEXT" button.

Select devices by sliding available emitters and sensors to the right.

If all emitters don't show, turn emitter power strip off , wait 10 seconds, then turn back on again

Hit Refresh and the emitters should begin to show

If vibrate and/or motion sensors don't show, make sure the sensor lights are aligned and face each other. Both lights will show green when sensors are communicating and both sensors should begin to show

Press the "NEXT" button.

Select the "SCRUB" cycle method and the "FIXED" cycle method.

Press the "NEXT" button.

Select the "CUSTOM TIME," Choose "60 minutes," select "OK," Press the "NEXT" button.

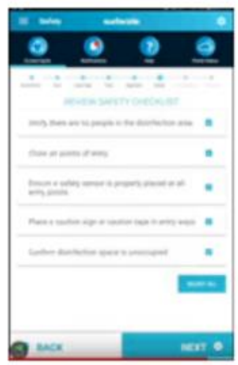
Line all three laser targets on the "A" target on the wall by sliding the left or right. Fine movements can be made by pressing the

Press the "SET TARGET" button when all laser targets are aligned.

Line all three laser targets on the "B" target on the wall by sliding the left or right. Fine movements can be made by pressing the

Press the "SET TARGET" button when all laser targets are aligned.

Perform the safety checklist. Ensure each statement is correct

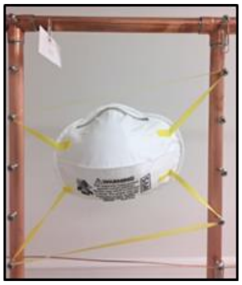


MASK DISINFECTION (CYCLE 1 FRONT OF MASKS)

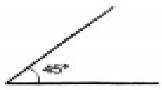
1. Rack Tech will don full PPE (double gloved, eye protection, gown, shoe covers, mask and hair bonnet)
2. Disinfect workspace; must allow for appropriate time for disinfectant instructions
3. Ensure that paper clip is to the left side of each frame
4. N95s should be prepared one at a time. There should be NO BATCHING
5. Open one Brown Paper Bag
6. Ensure required content (one index card and one mask) is present
7. Remove index card and confirm that the mandatory labeling requirement is present.
   - If card in incomplete, place card back in bag and push to side until the content of all bags have been assessed
8. If card is complete, remove and inspect N95 and its bands for any signs of damage or compromised integrity
   - If damaged, place back inside brown bag with index card and push to side until all masks have been assessed
9. If no damage,
   - attach index card to clip located in the upper left corner within one frame; card must always be to the left
   - hang corresponding mask inside same frame
10. Discard brown bag
11. Repeat process until each frame is filled with an index card and a N95
12. NOTE: If there are not enough N95 masks to fill the rack start using frames in the center and radiate outwards.
13. The Rack Tech will inform the UV Tech of readiness for the count and will provide the following information in the yellow columns and reason for waste
    - Total number of each mask type received
    - Number of each mask type wasted
    - Information for each mask wasted
14. The UV tech
    - Documents quantities in the two yellow columns and reason for wasted masks
    - Calculates number of each mask type processed (green column) and confirms quantities on rack
    - Writes in each column total in the yellow and green fields total fields
    - Staples the decontamination and corresponding wasted log sheets together

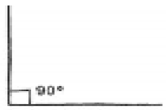
NOTE: Configuration of the masks on the rack will depend on the specific N95 model. Hang like masks together. And in all instances, the N95s should be placed in a manner that allows for all surfaces to be exposed to the light.

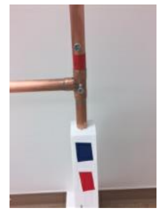
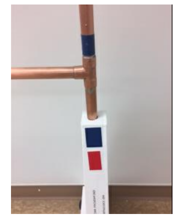
- *Any mask received with a different catalog# (*) should be hung like the mask pictured that it most resembles

15. Mount the UV sensor as indicated in the picture; sensor must always be at a 45^{O} angle, looking to the right and on the bottom left side of the rack above the lowest screw
    - When handling never touch the white circle on back of sensor
    - BE CAREFUL NOT TO TANGLE OR PULL ON THE UV SENSORCORD
    - The red and blue tape on the wooden base identifies the side of the wooden base on which the monitor should be attached for each cycle.

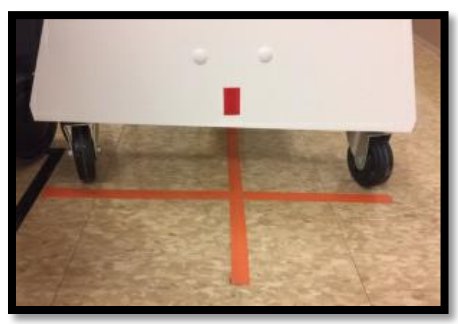




16. Roll the frame in front of the emitters (left side first)
    Do NOT move emitters from outlined spaces on the floor
17. Align the red tape on the bottom of the frame with the orange tape on the floor to ensure proper positioning. Lock wheel on both right and left side of rack, if wheel locks available





18. Carefully connect and secure UV Sensor to cable

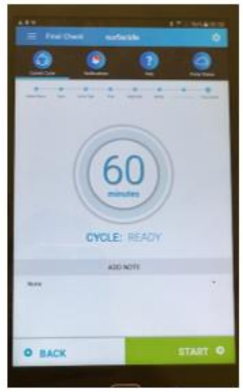
19. Doff and discard PPE, close garage door

20. Exit the room ensuring that the garage door and entry door is closed completely

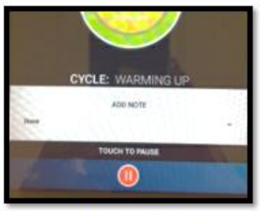
21. Set exterior door timer to 12 minutes and inform UV Tech that load is ready to run

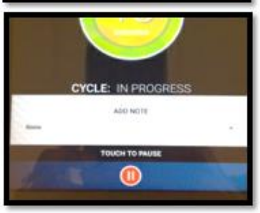
Hit RESET on the UV monitor

Set your timer to 12 minutes. Start cycle immediately after timer starts



After warm-up cycle will start and Light Meter will start reading dose exposure





When timer alarms at 12 minutes, pause the cycle in the Surfacide app.

20. Any value 1 J/cm^2 = PASSING

MASK DISINFECTION (CYCLE 2 BACKSIDE OF MASKS)

Document the reading as shown on the Light Meter under the 1st Cycle heading. Output should be >1 J/cm^2.

*If not >1 J/cm^2, CYCLE MUST BE ABORTED AND RE-RUN

Don clean gloves
DO NOT touch the N95s.
Remove UV sensor from frame
Place hands on the red tape on the lower frame to move never place hands on frame to move

Roll frame out of position and rotate the frame 180 degrees to treat the opposite side of the N95s. BE CAREFUL NOT TO HIT THE UV SENSOR
Mount the UV sensor as indicated in the picture below:

Align the red tape on the bottom of frame with the orange tape on the floor to ensure proper positioning.

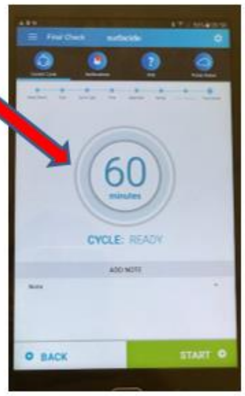
Dof and discards gloves, close garage door and exit room ensuring room is clear and all doors are closed

Hit RESET on the Light Meter UV monitor

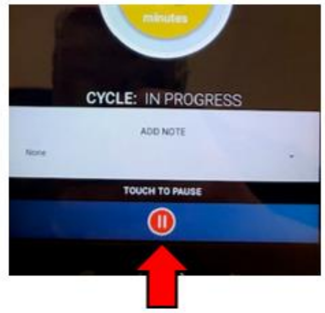
Select button "4" to reset meter to zero

Set your timer to 12 minutes. Start cycle immediately after timer starts.

*IF less than 13 minutes is showing on the app, you must perform the emitter calibration process again



When your timer alarms at 12 minutes, pause the cycle in the Surfacide app.



Document the reading as shown on the Light Meter under the 2nd Cycle heading. Output should be >1 J/cm^2.

N95 RESPIRATOR DECONTAMINATION LOG SHEET

Date: ______________

Shift: ______________

Load #				
LIGHT METER READING	1st Cycle	2nd Cycle	3rd Cycle	4th Cycle
Cycle Passed > 1.0				
N95 RESPIRATOR DESCRIPTION & CATALOG#		TOTAL NUMBER EACH MASK TYPE	NUMBER OF MASKS WASTED	NUMBER OF MASKS PROCESSED
3M Teal Blue Mask (1860)				
3M White Mask w/ red straps (1870)				
3M White Mask w/ Yellow Straps (8210)				
3M White Mask w/ Yellow Nozzle & straps (8511)				
3M White Mask w/ Blue Straps (9210)				
SAS White Mask (8617)				
Sperian Masks (W1400)				
Kimberly Clark Peach & White Mask w/ Blue Straps (46767)				
TOTALS (WRITE TOTALS FOR EACH COLUMN)				

*If not >1 J/cm^2, CYCLE MUST BE ABORTED AND RE-RUN

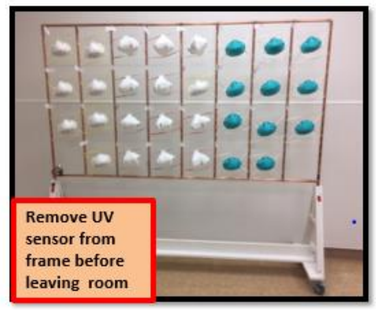
Put on clean gloves

DO NOT touch the N95s.

Remove UV sensor from frame and attach to frame for next load

Place hands on the red tape on the lower frame to move

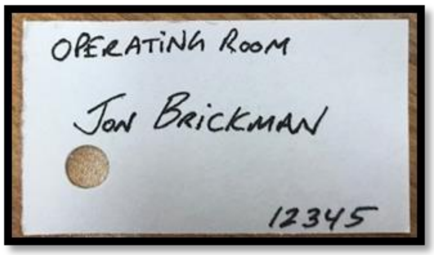
Roll frame down the corridor to the sorting room (02220) into parking space outlined on the floor.



MASK STRAP DISINFECTION AND PACKAGING

NOTE: NO BATCHING – ALL N95S SHOULD BE HANDLED ONE AT A TIME

1. Packaging Tech will remove one mask from frame, wipe bands with disinfectant wipe and hang mask on screw within frame nearest index card
2. Repeat process until all bands have been wiped.
3. Bands must be allowed to disinfect per time as required by disinfectant wipe mfg.
4. Set timer after last mask is hung
5. During timer count-down, gather a Ziplock bag for each mask and place a green sticker on each to indicate disinfection has been completed.
6. When timer alarms remove an Index card from a frame and punch a hole in the card



- There should be no more than 3 punches on any card, if more than 3 holes noted, place card and N95 to the side but do not discard

7. Place card in zip lock bag
8. Remove corresponding N95 from frame
9. Inspect for damage,
   - If noted, place card and N95 to the side but do not discard
10. If condition is visually acceptable, place N95 in the zip lock bag and seal.
11. REPEAT PROCESS UNTIL ALL MASKS ARE REMOVED FROM FRAME

12. Place zip lock bag in appropriate department bag.
13. Call department to notify that N95s are ready for pick up
14. Roll empty frame back to the Mask Processing space (A2 on Layout, 02325) then return to Packaging Room
   - Any damaged masks or those with holes >3 should be given to the UV Tech for documentation updating. UV Tech will dispose of mask after documenting information

REFERENCES

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7. Surfacide N95 FFP Mask Reprocessing Protocol. https://static1.squarespace.com/static/56d3630407eaa0756aebf254/t/5e8b65e77a60de0c3e03e3c5/1586193902315/Surfacide+N95+Decontamination_final+written+protocol+REVISED.pdf

SLIDE DECK

University of Chicago
UVGI N95 Mask Disinfection
Progress summary and test results
April 15, 2020

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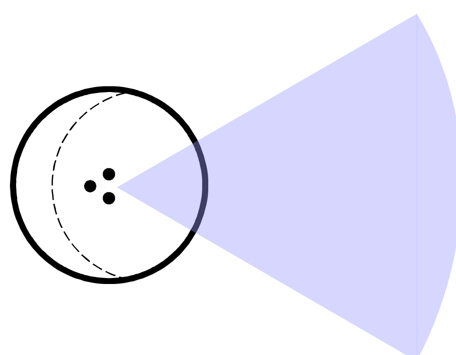
Surfacide Helios UV-C Germicidal Irradiation System

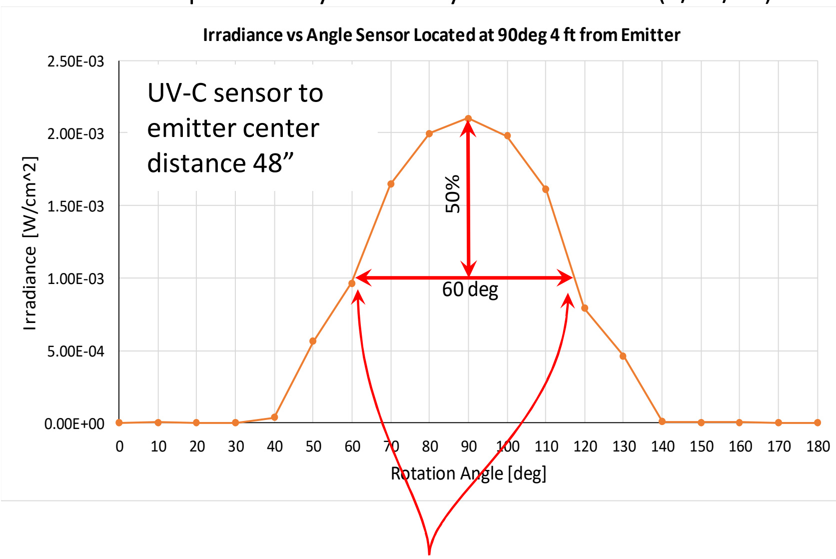
surfacide.com

- 3 emitters work together
- Motorized rotational sweeps synchronized by laser targeting
- Each emitter contains three tubular mercury vapor lamps
- Lamps 1.2 m long, arranged in 1” equilateral triangle
- Nominally parabolic reflector directs UV light forward in 60˚ fan

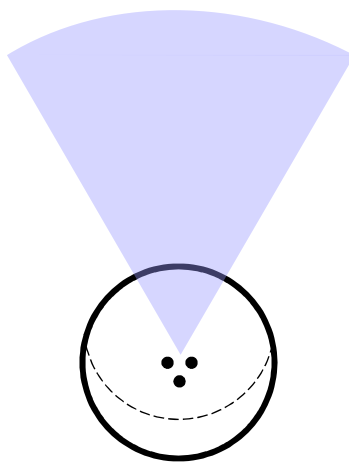


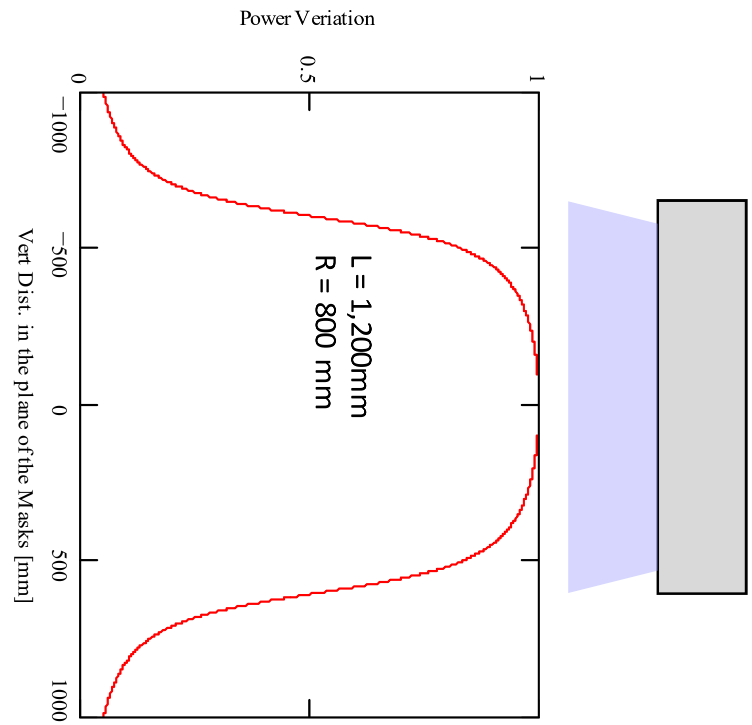
Single Surfacide Helios emitter irradiance vs. horizontal fan angle

Data provided by Devlin Thyne Surfacide Inc (3/26/20)

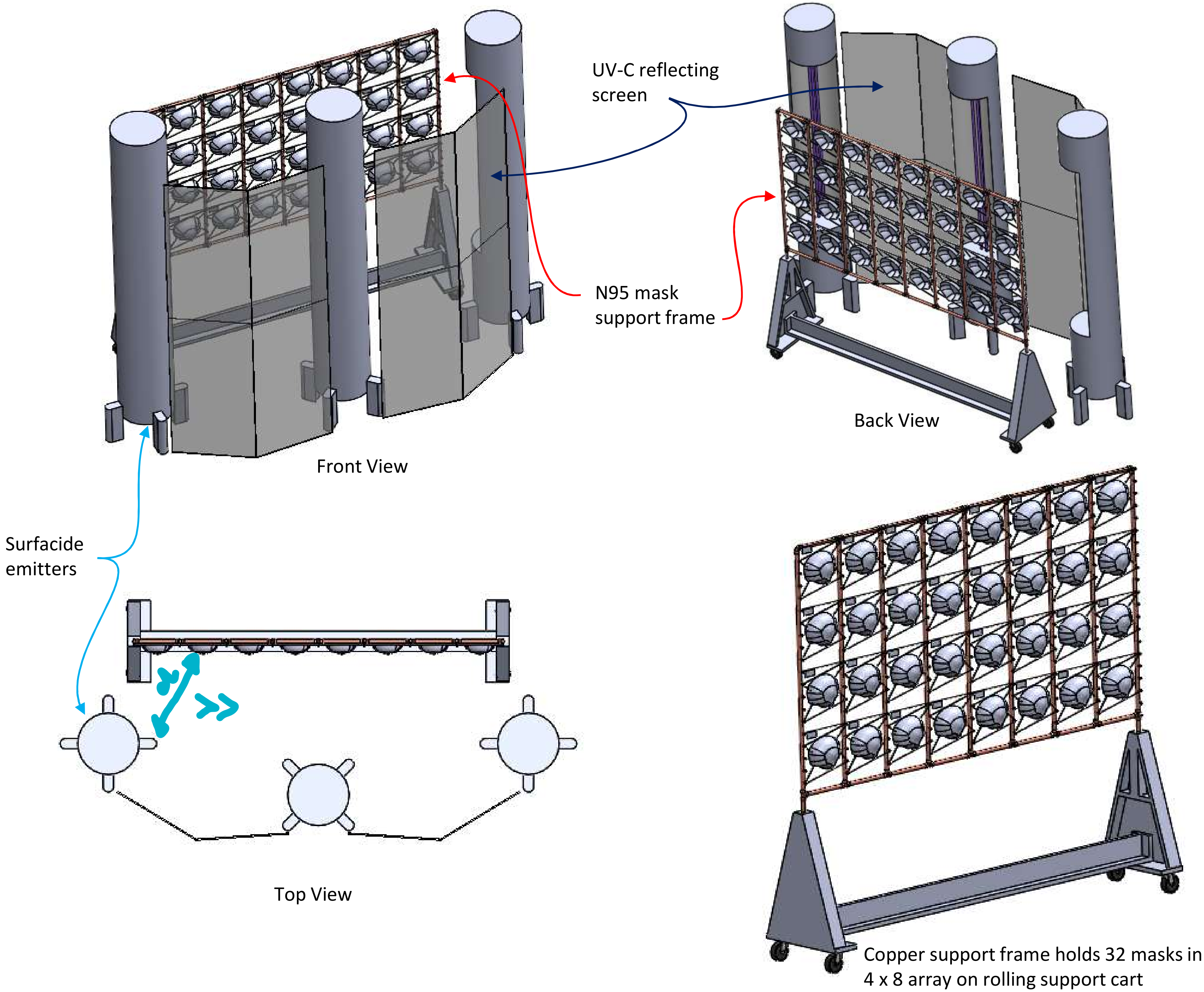


A hor. full angle of 60 deg. results in a 50% reduction in peak power.



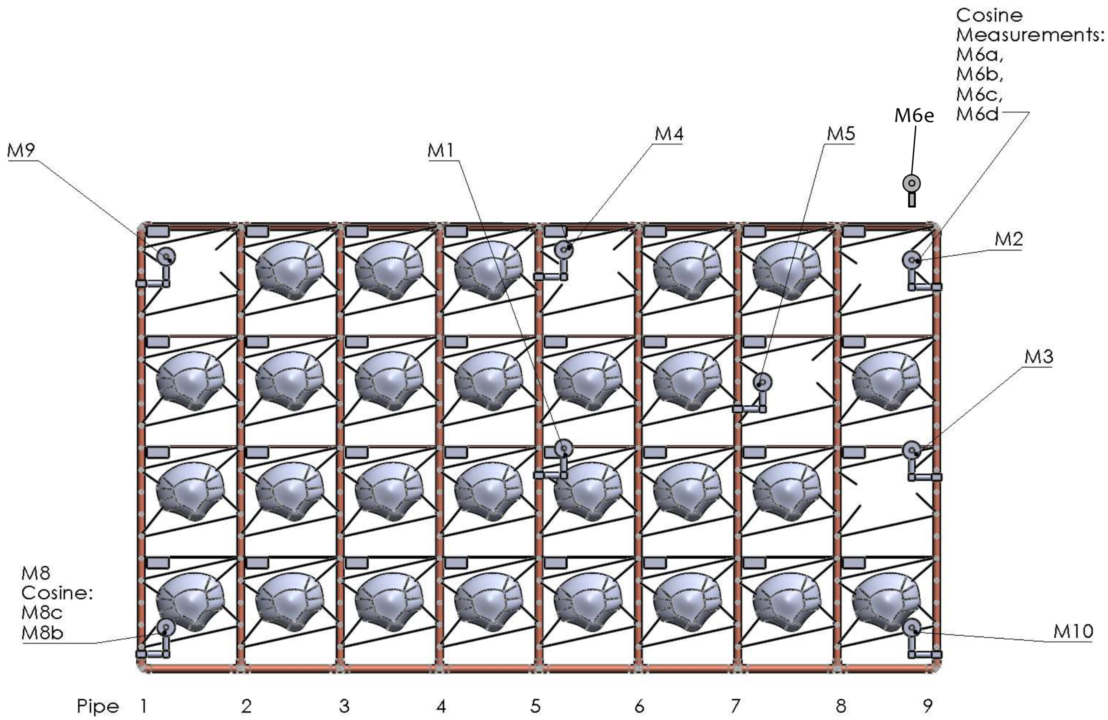


Power variation in vertical direction for lamps 1,200 mm long and masks located 800 mm away.


UV-C reflecting screen
N95 mask support frame
Front View
Back View
Surfacide emitters
Top View
Copper support frame holds 32 masks in 4 x 8 array on rolling support cart

Requirement: All surfaces receive > 1 J/cm^2 based on Heimbuch report to FDA

https://www.ara.com/news/ara-research-mitigate-shortage-respiratory-protection-devices-during-public-health-emergencies

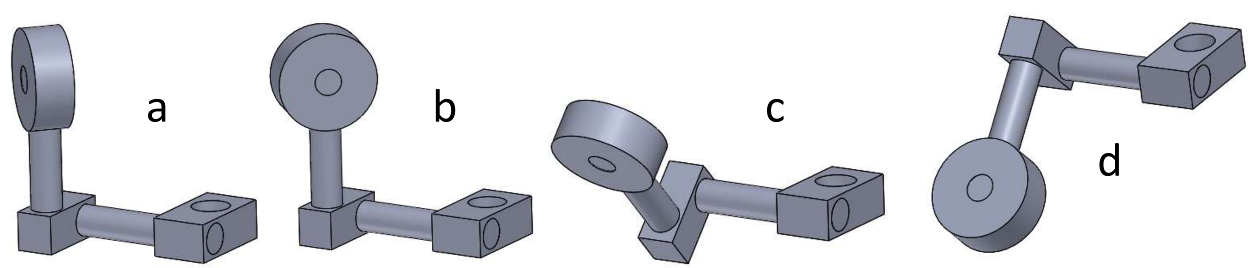


UV Spectrophotometer used to measure energy deposited at several locations on support frame

Measurements M1, M2, M3, M4, M5 made in upper right quadrant with face of sensor in plane of frame

Measurements at M8, M9, M10 made to evaluate symmetry of dose in four quadrants

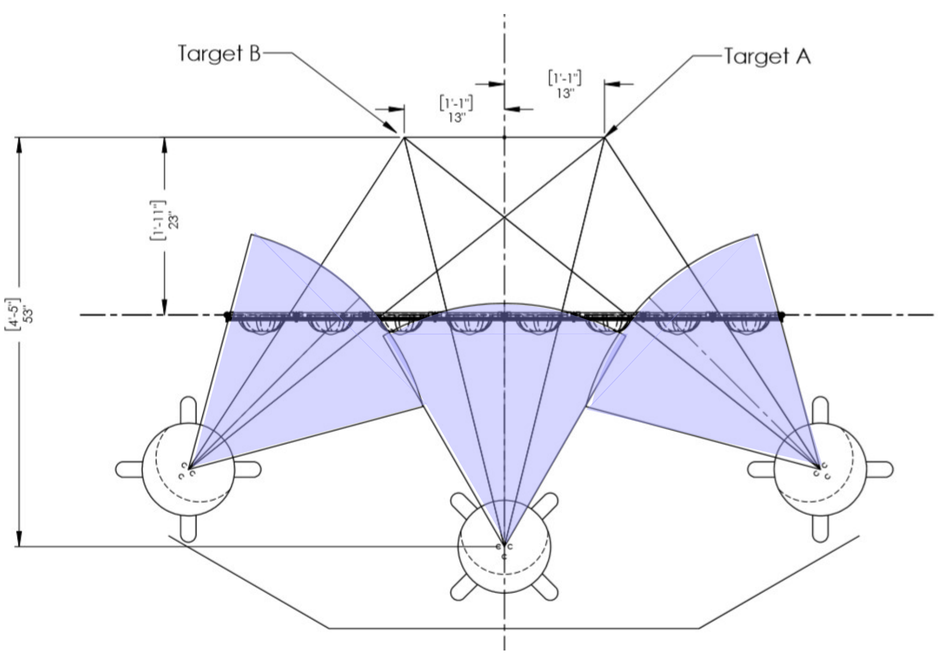
- Cosine measurements M6, M7 made at same locations as M2, M4 respectively.
- Additional cosine measurements at 8b, 8c.
- Face of sensor tilted 45˚ in orientations a, b, c, d (left, right, down, up) to evaluate energy delivered to curved surfaces of masks at edges of support frame.

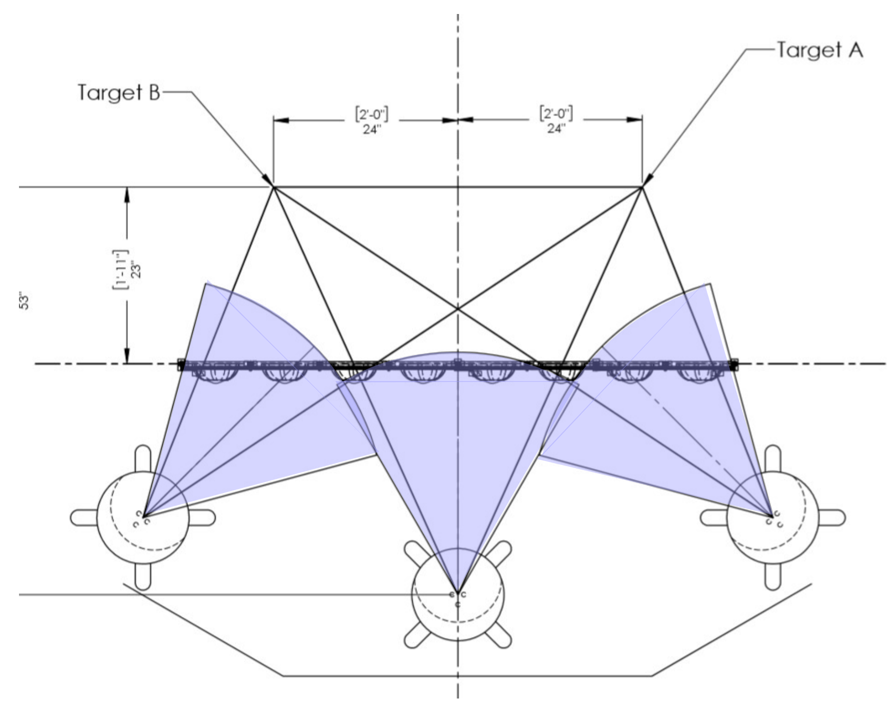


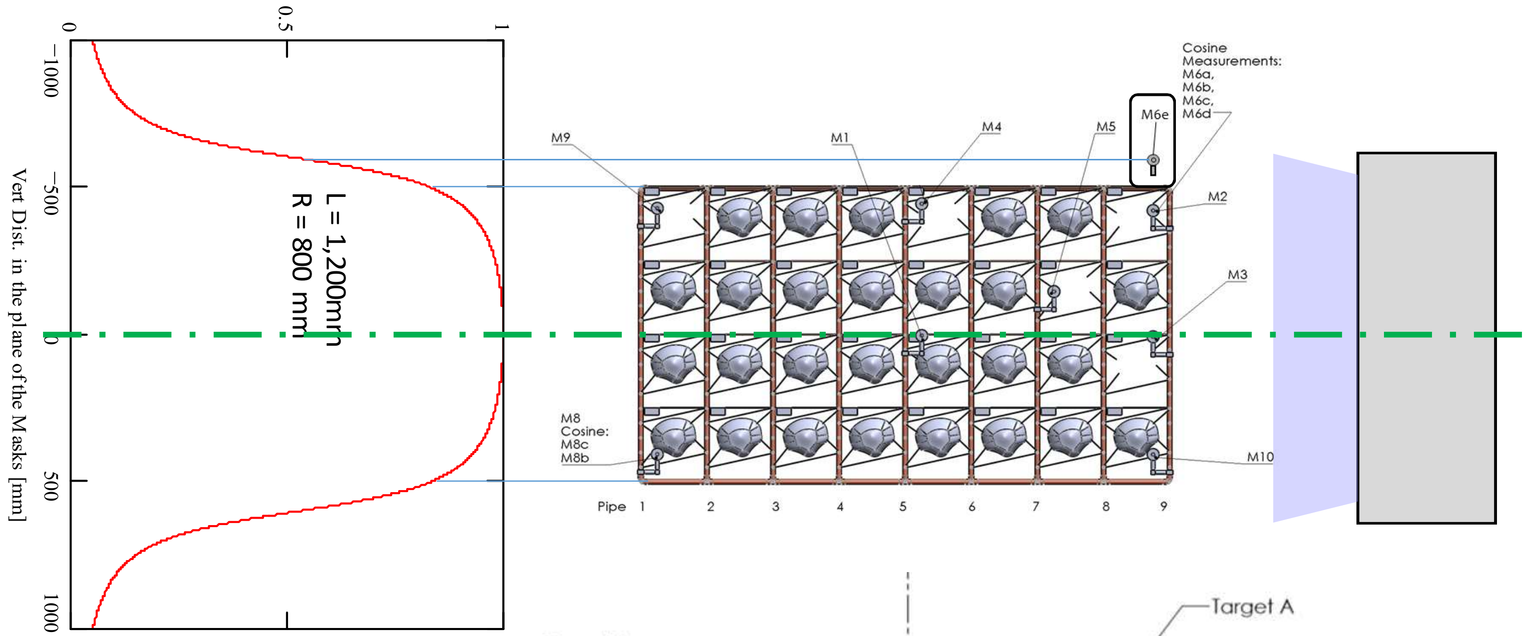
Emitters use laser Targets A and B positioned on wall (53 inches from center of center emitter) behind mask support frame to synchronize motorized rotational sweeps

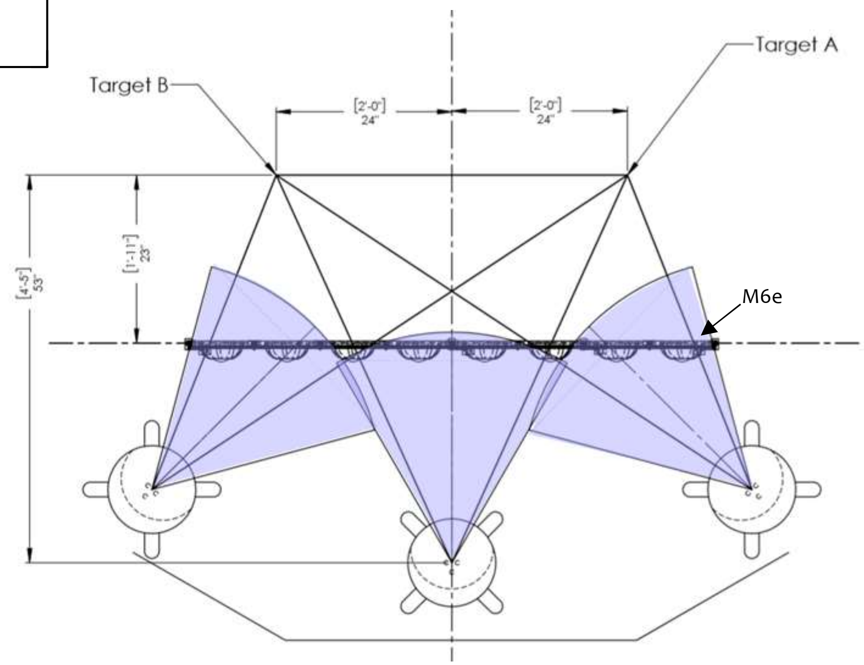
Each emitter sweeps the centerline of its 60˚ fan from one target to the other and oscillates back and forth in time with the other emitters

Several sweep conditions considered
Shown below: Targets placed 13” (target separation 26”) and 24” (target separation 48”) from centerline of full assembly



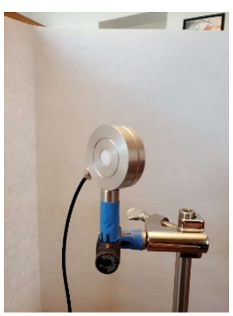






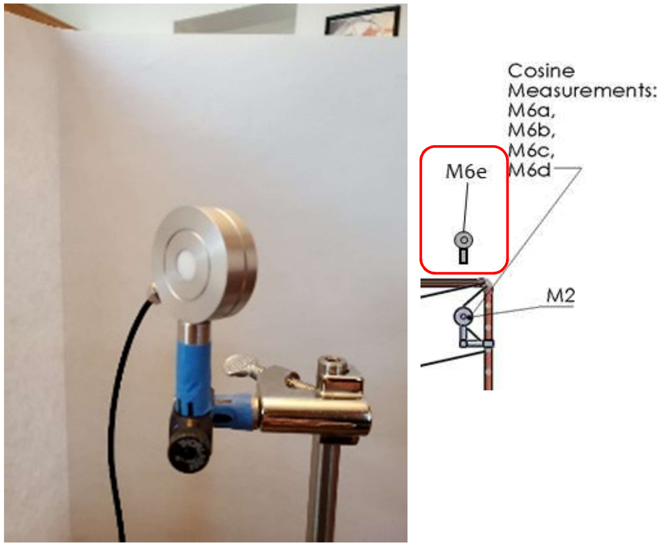
Measurements to evaluate sweep conditions made at M6e

- Same horizontal position as M2/M6 but 7" higher (outside frame)
- Same orientation as M6a (sensor facing away from right emitter



Optimize sweep and exposure time at M6e

- Extreme position outside frame
- Orientation receives weak illumination from far-away center emitter and grazing illumination from nearby right emitter
- Vary exposure time and target-to-centerline distance



Measurement	Time [min]	Target Dist. [in]	J/cm^2
M6e	9	13	0.711
M6e2	9	24	0.837
M6e3	9	35	0.815
M6e4	11	24	1.07
M6e-s2	11	18	0.858

Conclusions:

- Optimal target-to-centerline = 24”
- 11 min exposure meets 1 J/cm^2 requirement even when weakly illuminated and above mask support frame

At each spectrophotometer location/orientation, measurements recorded as

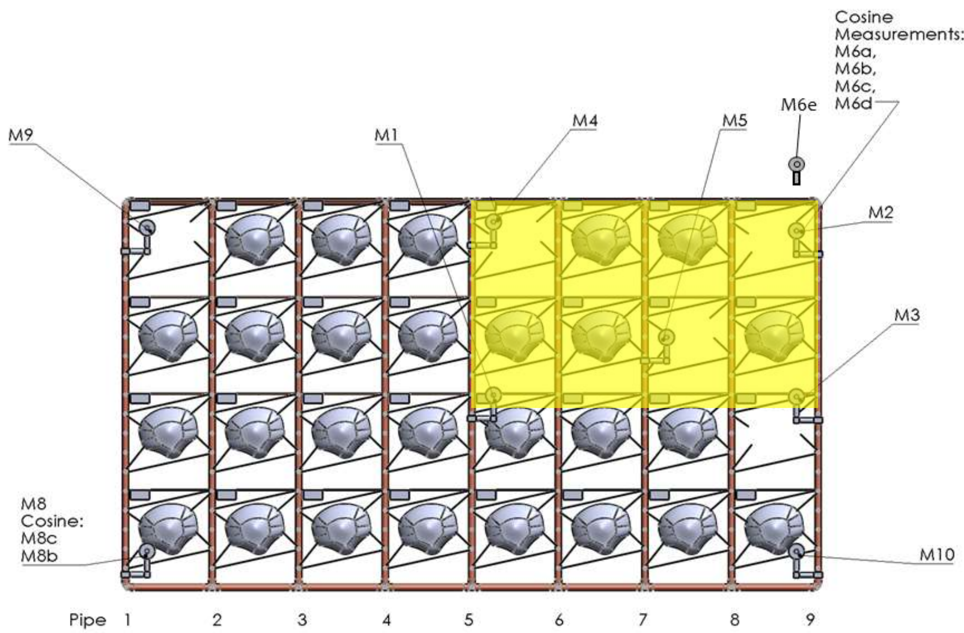
(1) Instantaneous dose recorded every 4 seconds to evaluate heterogeneity during emitter sweeps

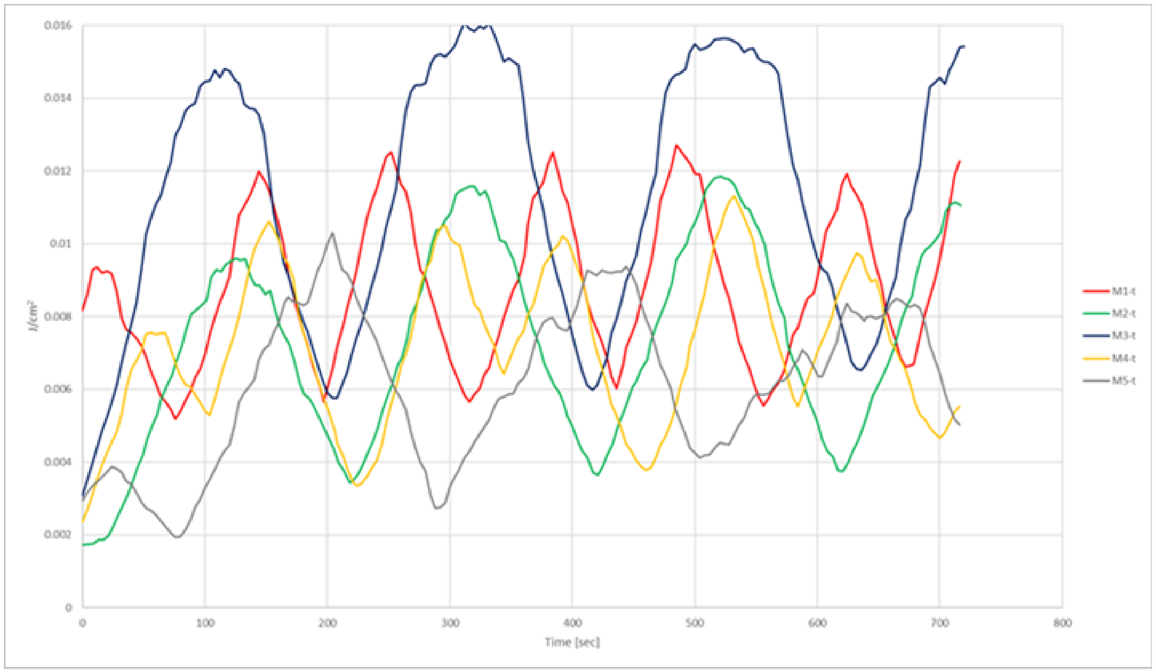
(2) Time to reach 1 J/cm^2

(3) Integrated dose over 9-12 min of irradiation

Upper right quadrant

- M1, M2, M3, M4, M5
- Sensor face in plane of frame

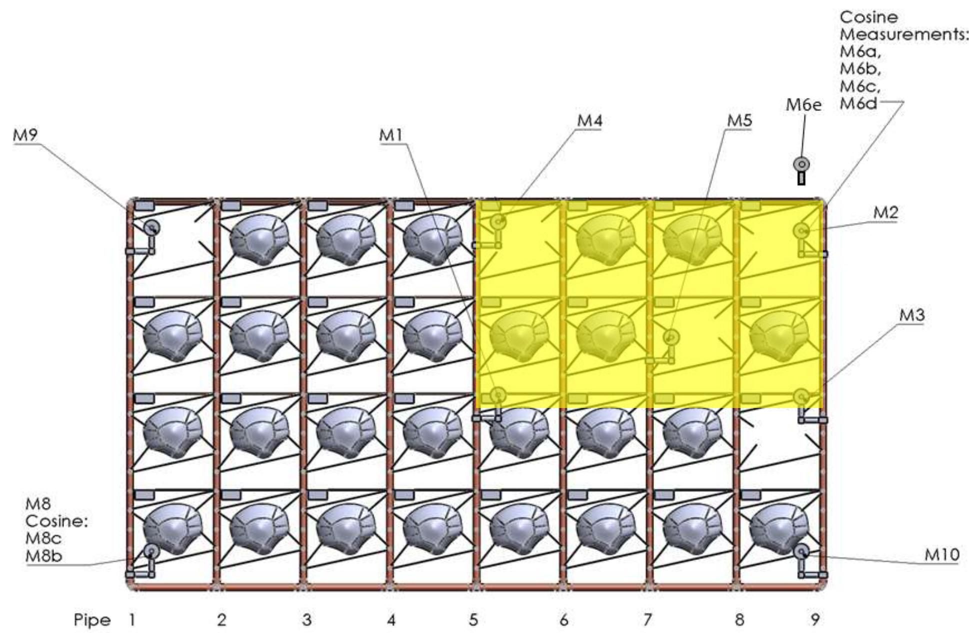




- Instantaneous dose at each location varies temporally as three emitters sweep side-to-side
- There appears to be a warm up period in the first 100-150 seconds
- Both could cause significant variability in total dose if exposure times are short

Upper right quadrant

- M1, M2, M3, M4, M5
- Sensor face in plane of frame

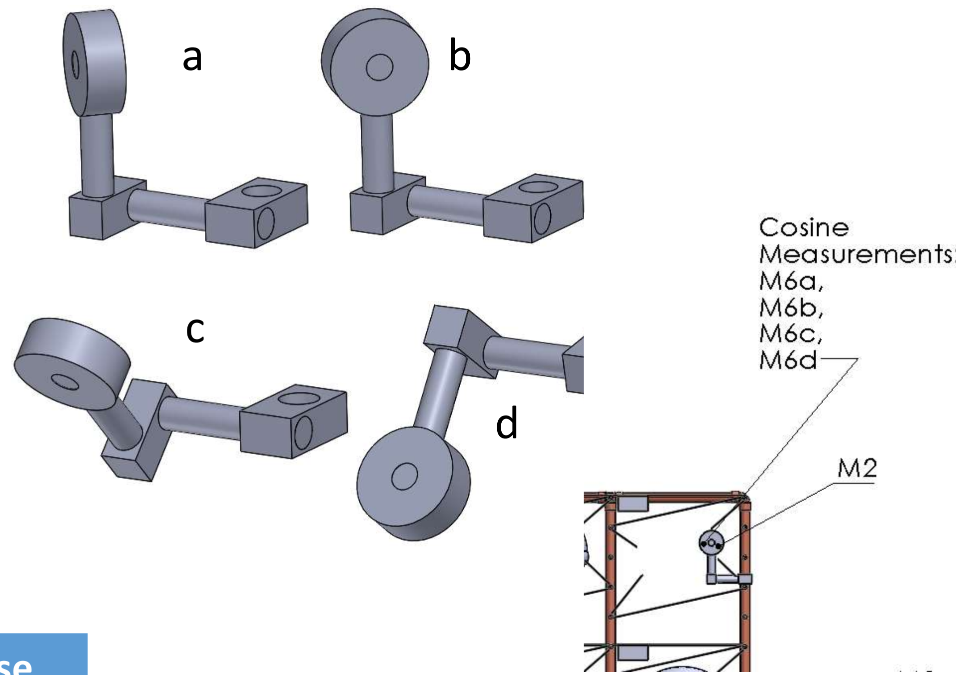


Location	Time to 1 J/cm² (m:ss)	9 min dose (J/cm²)	10 min dose (J/cm²)	11 min dose (J/cm²)	12 min dose (J/cm²)	9 min dose*12/9 (J/cm²)
M1	2:35	3.8	4.1	4.6	5.0	5.1
M2	3:31	3.0	3.4	3.7	4.1	4.0
M3	2:08	4.8	5.4	5.8	6.4	6.4
M4	3:08	3.0	3.4	3.4	4.0	4.0
M5	3:54	2.5	2.8	3.1	3.5	3.3

- All achieve 1 J/cm² requirement at < 4 min
- M1, M3 at mid-height vertically and closest to emitters horizontally receive highest dose
- M5, between emitters horizontally, receives lowest dose
- For exposures ≥ 9 min, temporal variability and warm-up do not significantly affect dose scaling (see last column where the 9 min dose is multiplied by 12min/9min to compare to the 12 min measurement)

Cosine effects – upper right corner

- M6a, M6b, M6c, M6d
- Sensor orientations a, b, c, d
- Compare to M2 (sensor flat)



Location/ Orientation	Time to 1 J/cm^2 (m:ss)	12 min dose (J/cm^2)
M6a	6:15	2.1
M6b	2:54	4.7
M6c	2:11	6.0
M6d	4:40	3.0
M2	3:31	4.1

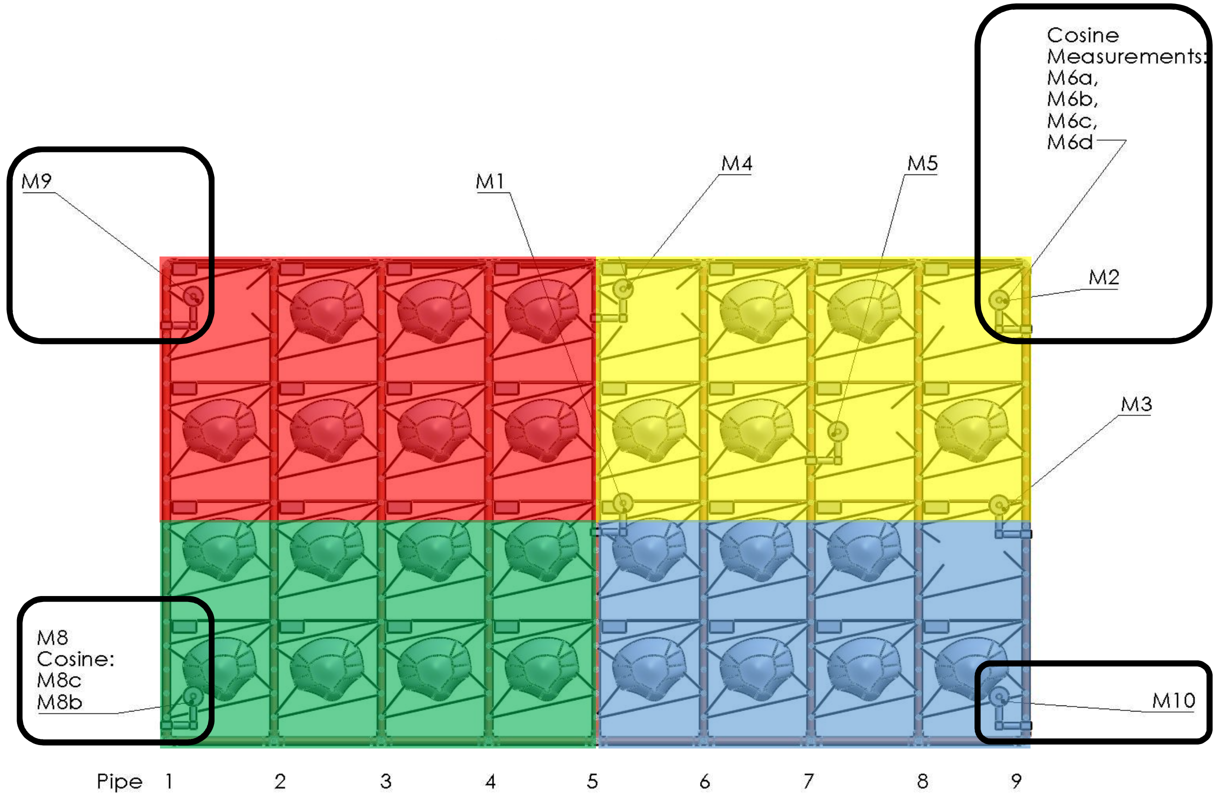
M6c with sensor tilted down receives largest dose

M6a with sensor tilted left (toward center, away from right emitter) receives lowest dose, but more than twice the 1 J/cm^2 requirement at 12 min

So far, all measurements from upper right quadrant only

We have assumed 4 quadrants are equivalent by symmetry

To check, compare 12 min integrated doses at M2, M8, M9, M10 with sensor face in plane of frame

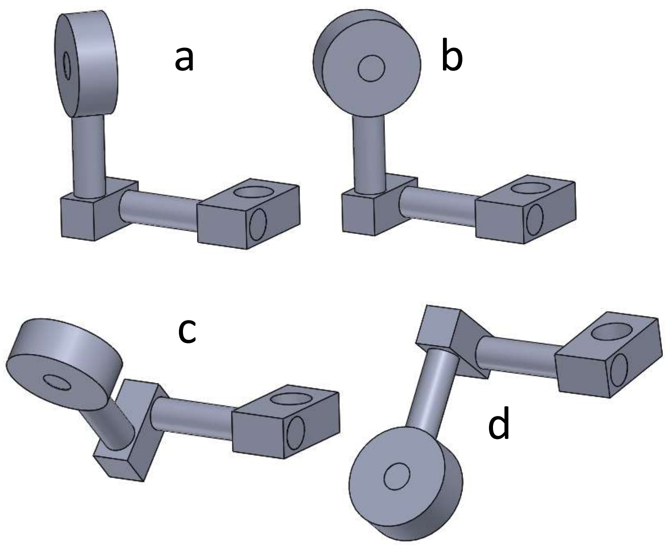


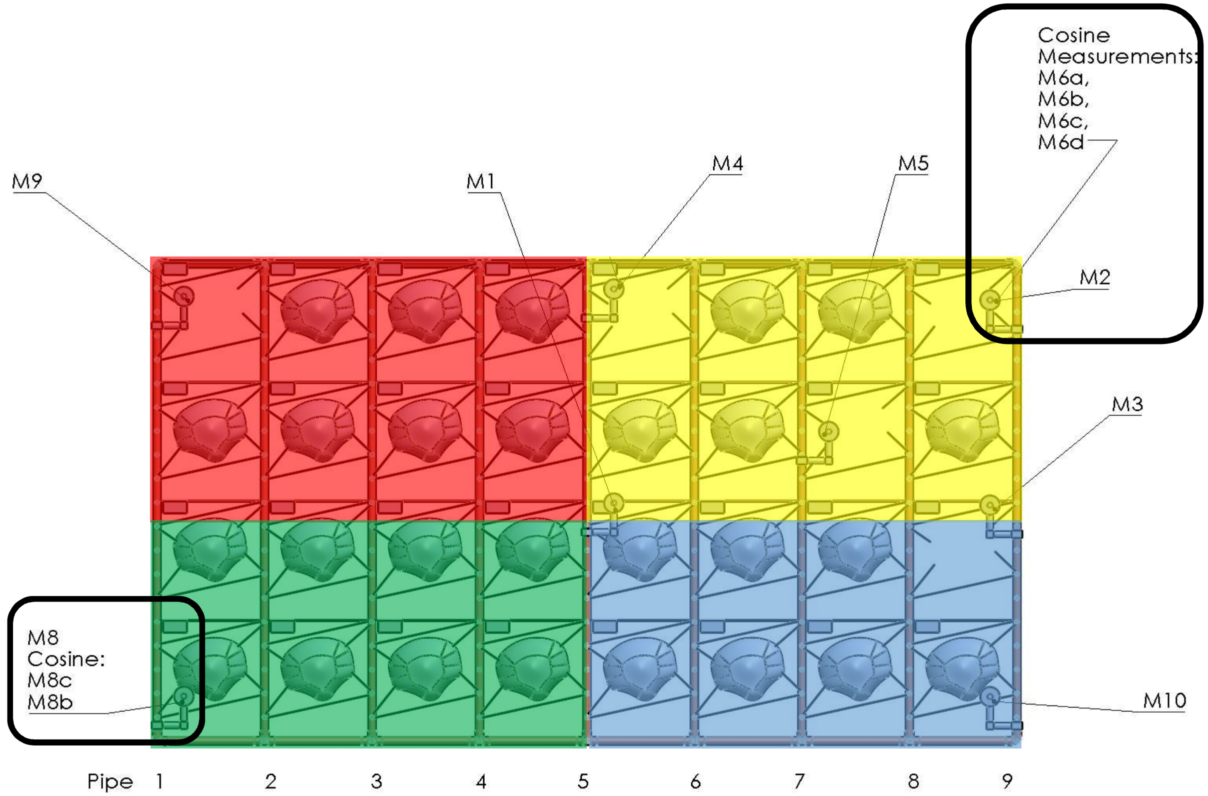
Location	J/cm²
M9	3.7
M8	3.7
M2	4.1
M10	4.9

Top-bottom somewhat consistent
Right side stronger than left

All >> 1 J/cm² at 12 min

Further symmetry check:
Cosine measurements at M6, M8
12 min exposure





Location/Orientation	J/cm^2
M2 (flat, same location as M6)	4.1
M6d (sensor tilt up)	3.0
M6a (sensor tilt left)	2.1
M8 (flat)	3.7
M8c (sensor tilt down)	2.2
M8b (sensor tilt right)	1.7

At each location, dose varies with orientation:
flat > vertical tilt > horizontal tilt

For each symmetry-related orientation pair, dose varies with location:
M2/M6 > M8

For all, dose > 1 J/cm^2 at 12 min

Exposure and measurement recommendations

- 12 min exposure time to significantly exceed 1 J/cm^2 at all locations/orientations
- Measure at M8b (weakest location/orientation) during all exposures to verify acceptable dose and check for consistency

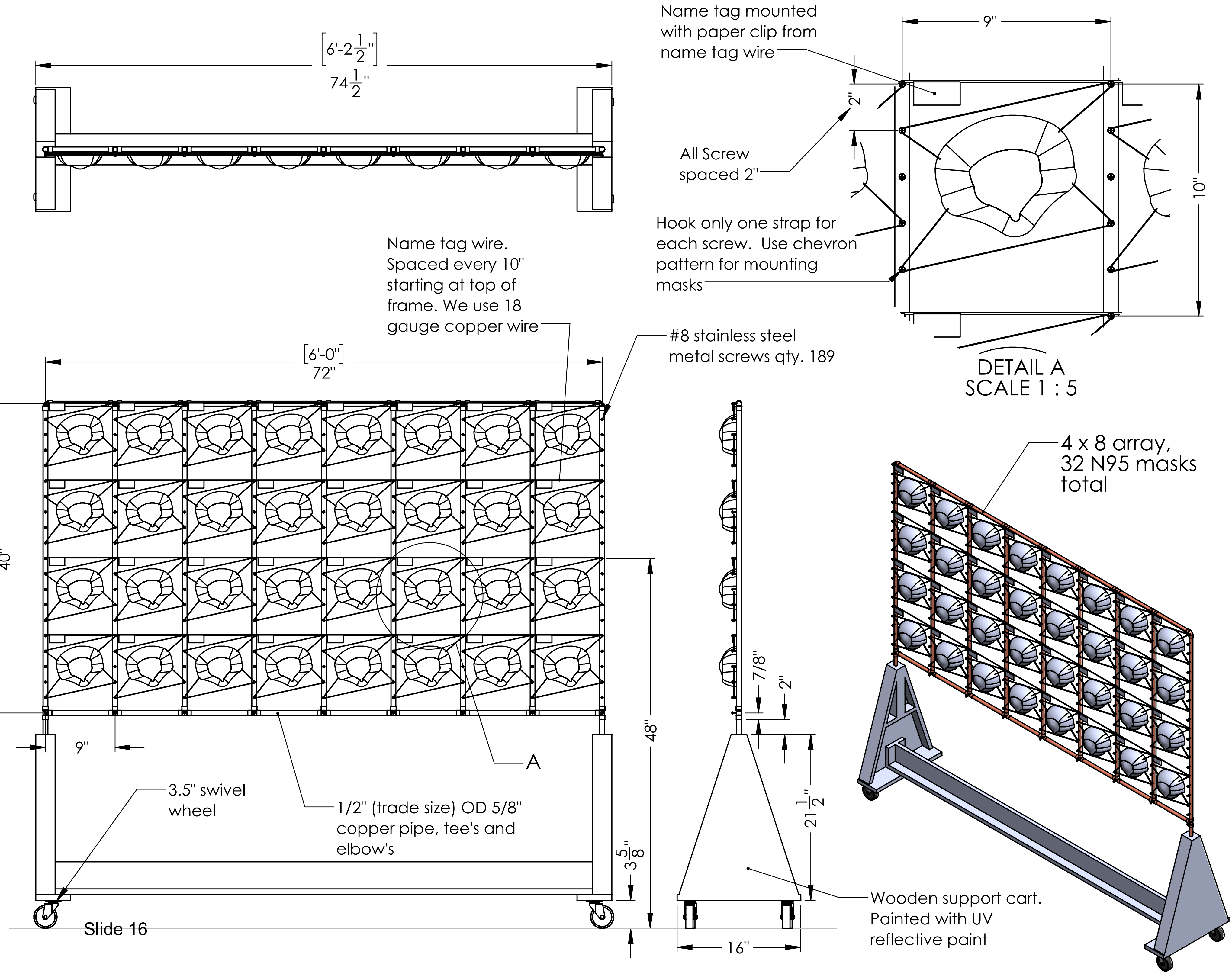
Estimated throughput

- Exposure time = 12 minutes per side
- Time per frame = 27 min
  - 2 x 12 min to expose front and back
  - 1 min to rotate 180˚
  - 1 min to roll new frame into room
  - 1 min to roll completed frame out of room
- Cycle time with 3 min buffer = 30 min

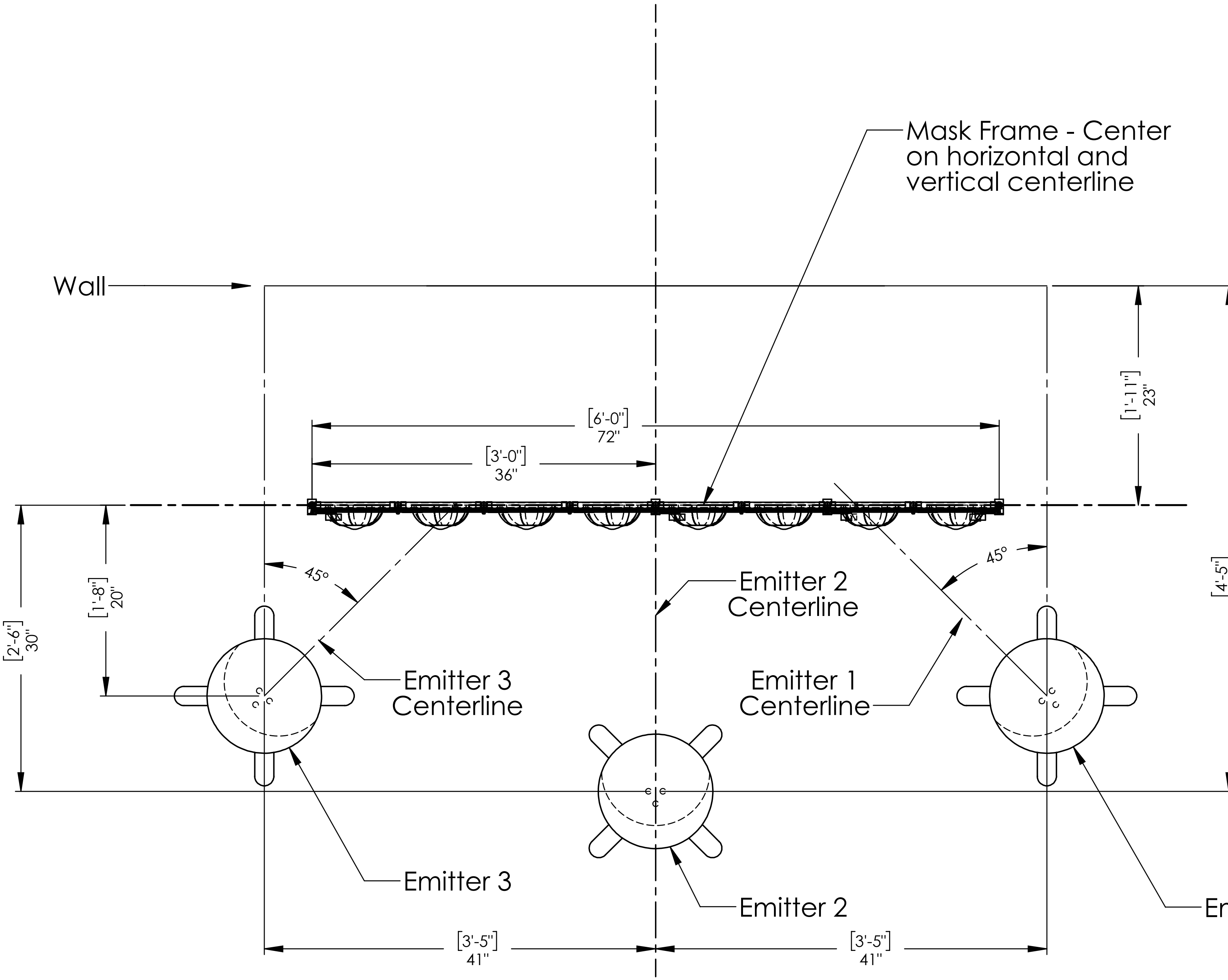
During exposures, additional frames can be loaded/unloaded – total of 5 frames available

Assuming personnel are available to work in shifts:
32 masks/frame x 2 frames/hour x 24 hours = **1536 masks per day**

Second setup would double throughput to **3072 masks per day**

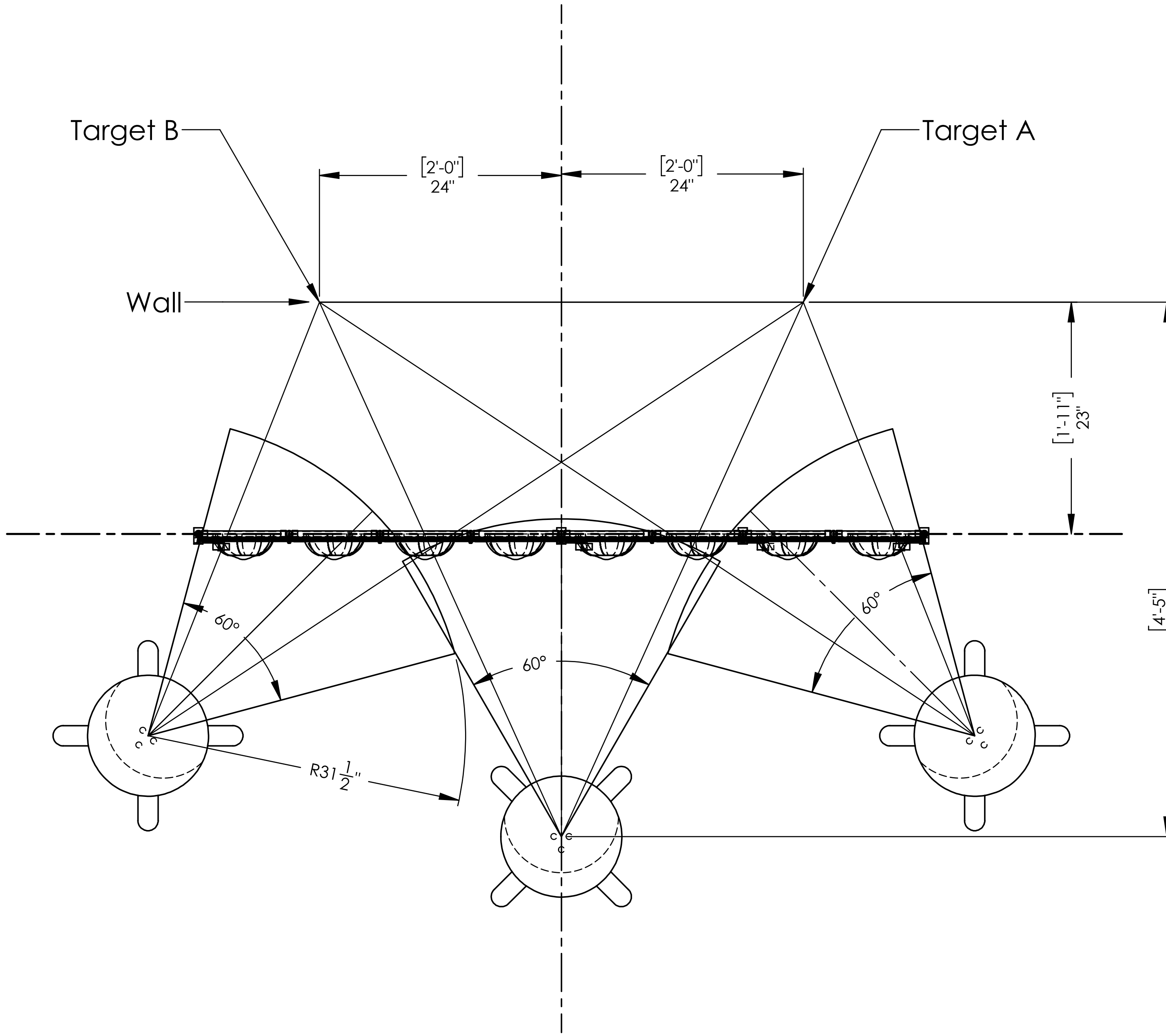

[6'-2 1/2"]
74 1/2"
Name tag mounted with paper clip from name tag wire
9"
2"
10"
All Screw spaced 2"
Hook only one strap for each screw. Use chevron pattern for mounting masks
DETAIL A
SCALE 1 : 5
Name tag wire. Spaced every 10" starting at top of frame. We use 18 gauge copper wire
#8 stainless steel metal screws qty. 189
[6'-0"]
72"
[3'-4"]
40"
4 x 8 array, 32 N95 masks total
7/8"
2"
48"
9"
A
21 1/2"
3.5" swivel wheel
1/2" (trade size) OD 5/8" copper pipe, tee's and elbow's
3 5/8"
Wooden support cart. Painted with UV reflective paint
16"

Surfacide Three Emitter Layout



Contact Peter Eng if you have any questions:
eng@cars.uchicago.edu

Surfacide Emitter Target Points Ver2



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