Far-UVC light for reducing microbial bioburden in cleanrooms

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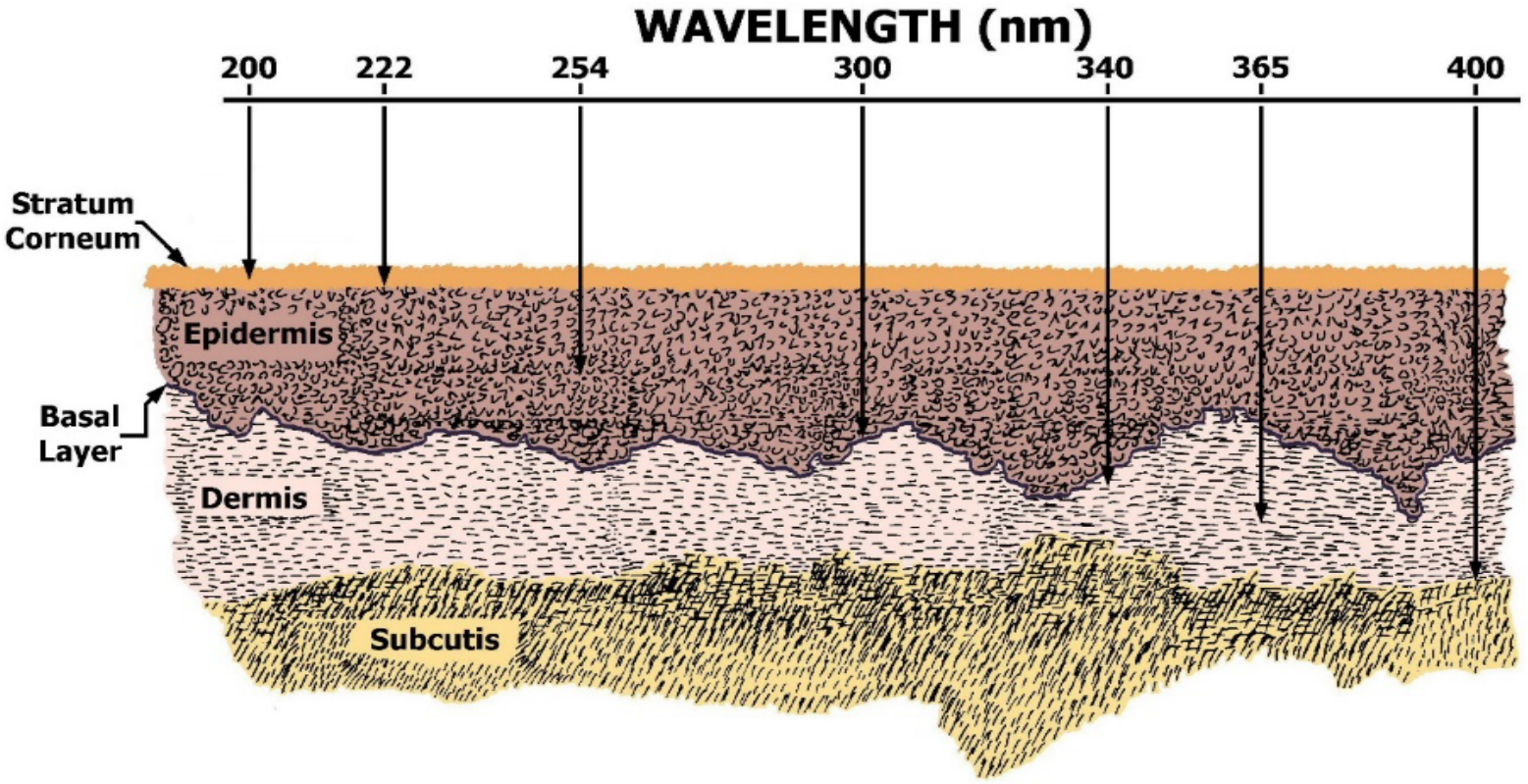
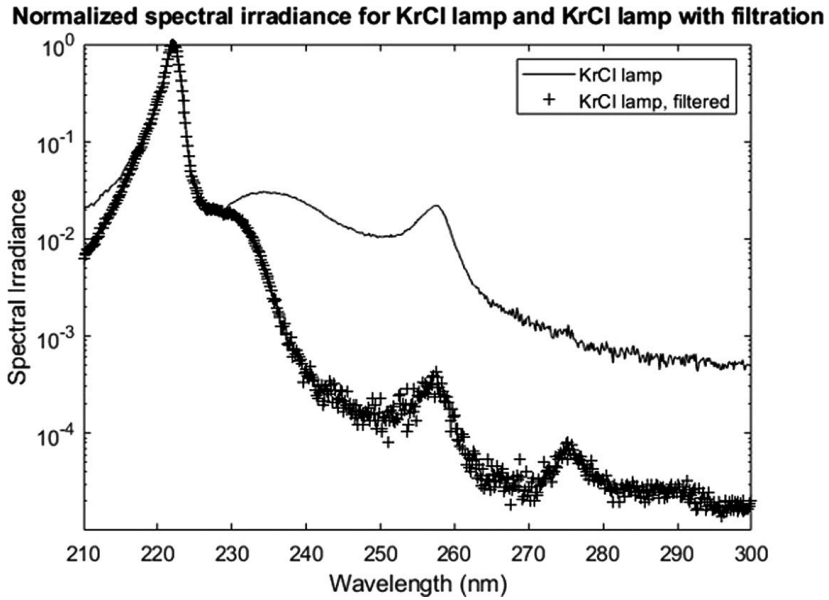
What is far-UVC?

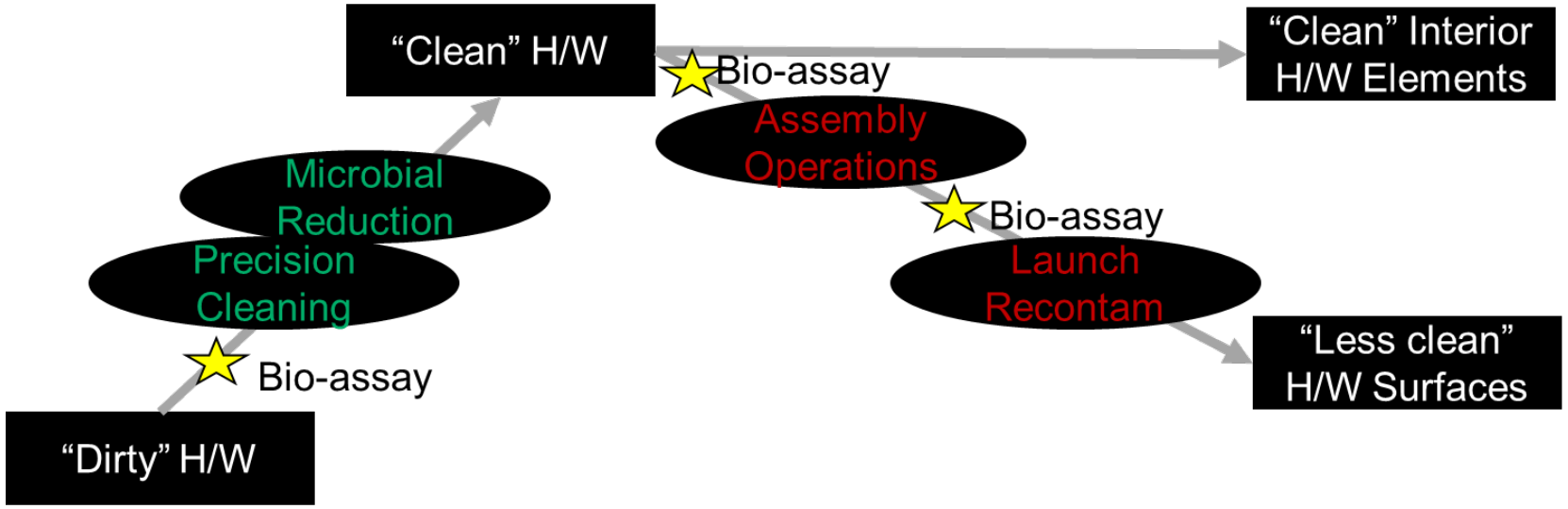




- Far-UVC sources are limited
  - KrCl excimer lamps at 222 nm (optically filtered)
  - LED technology for far-UVC is still on the horizon

Far-UVC for planetary protection

- Continuously expose entire cleanroom
- Passively inactivate microbes without harming occupants



Notes on the use of far-UVC

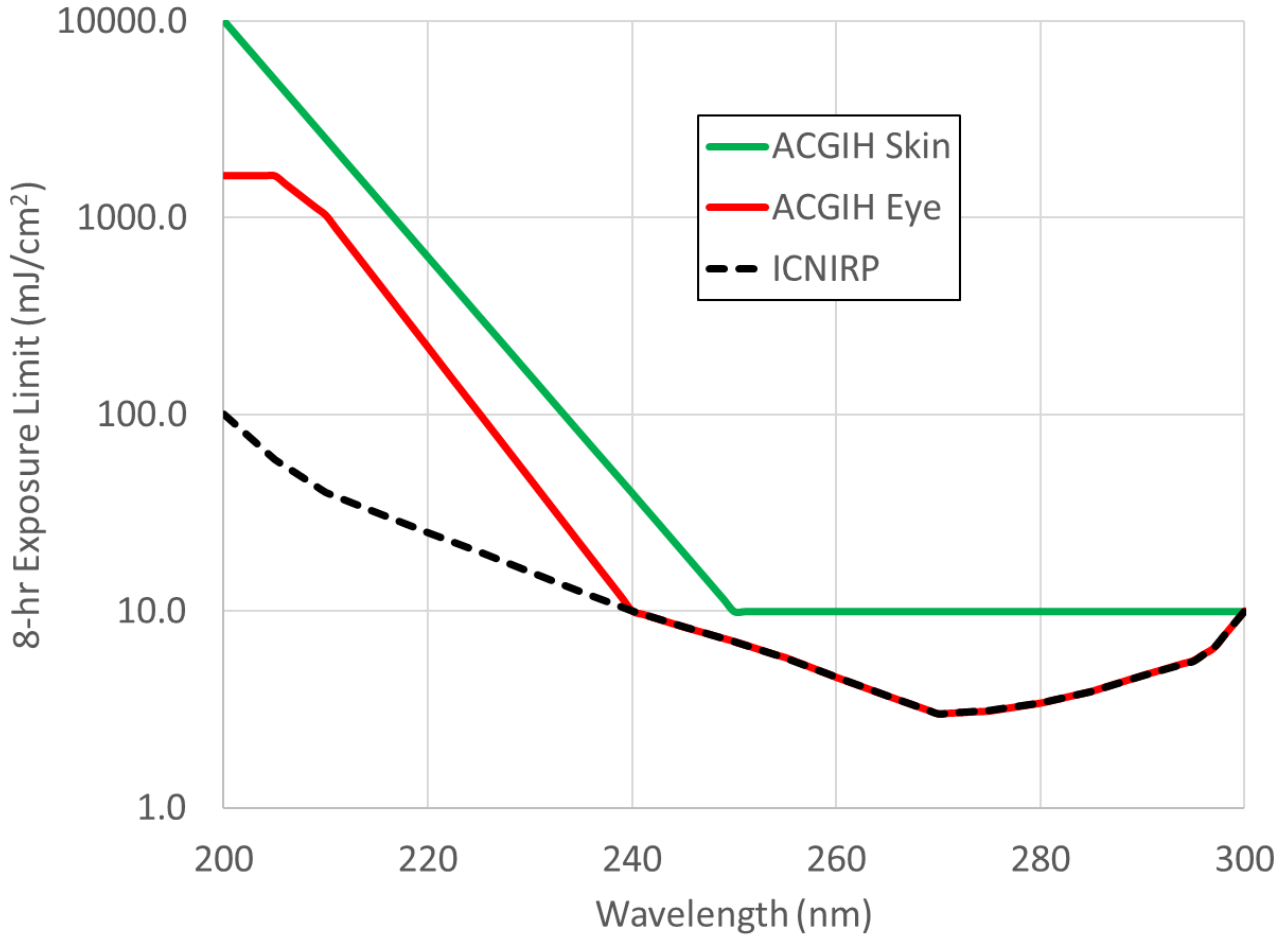
- Ozone formation and indoor air chemistry
  - Mitigated by HVAC system
- Microbiome effects
  - Likely minor compared to normal washing
  - Skin is largely unexposed, especially in cleanrooms
- Effects on materials
  - Minimal, some color change in polymers reported after simulation of 10 years of exposure

Key questions with far-UVC:

- Is it safe?
- Does it work?

Far-UVC safety

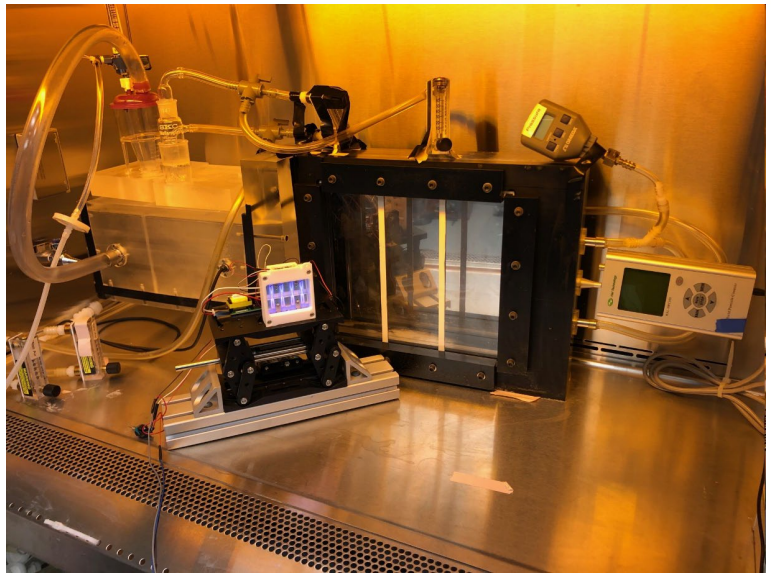
- Biophysical principals
- Growing number of peer-reviewed studies
- <u>Existing national and international regulatory frameworks</u>
  - ACGIH: American Conference of Governmental Industrial Hygienists
  - ICNIRP: International Commission on Non-Ionizing Radiation Protection

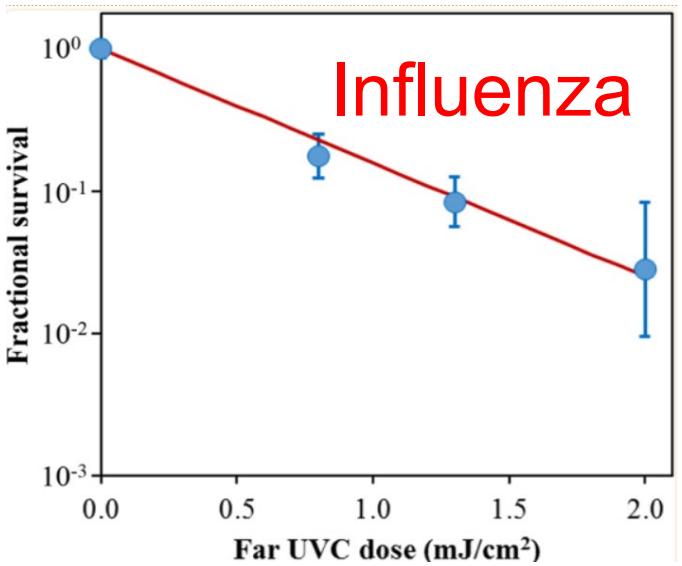


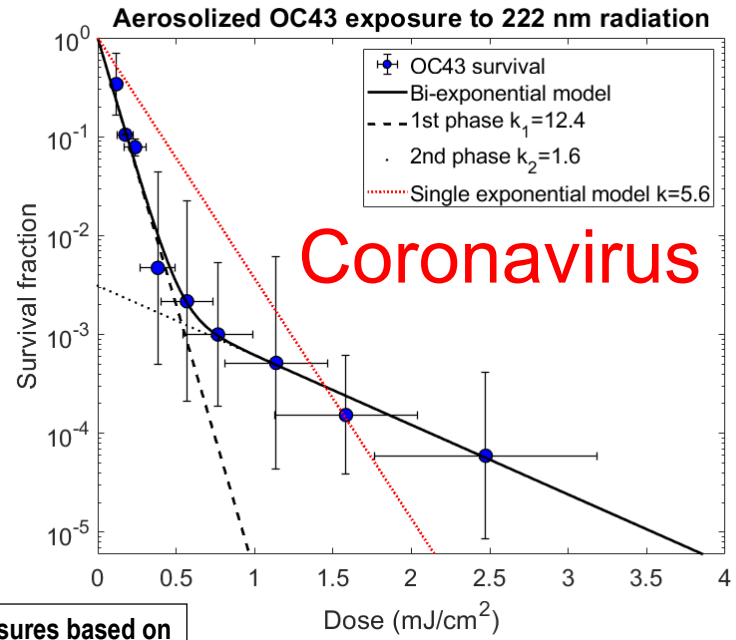
Key questions:

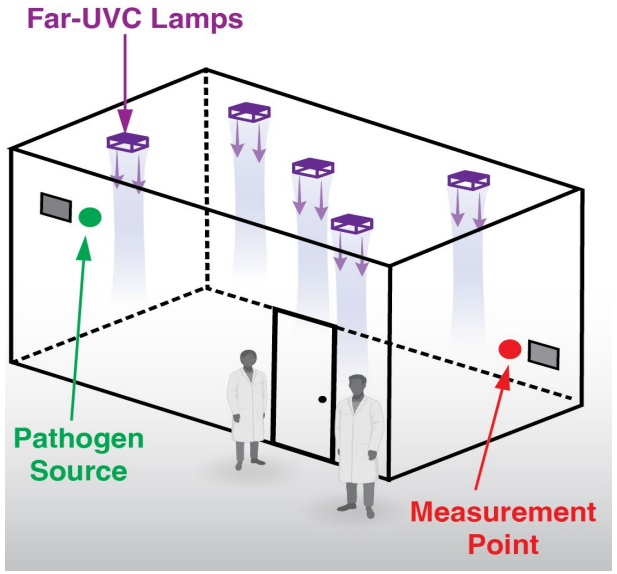
- Is it safe?
- Does it work?

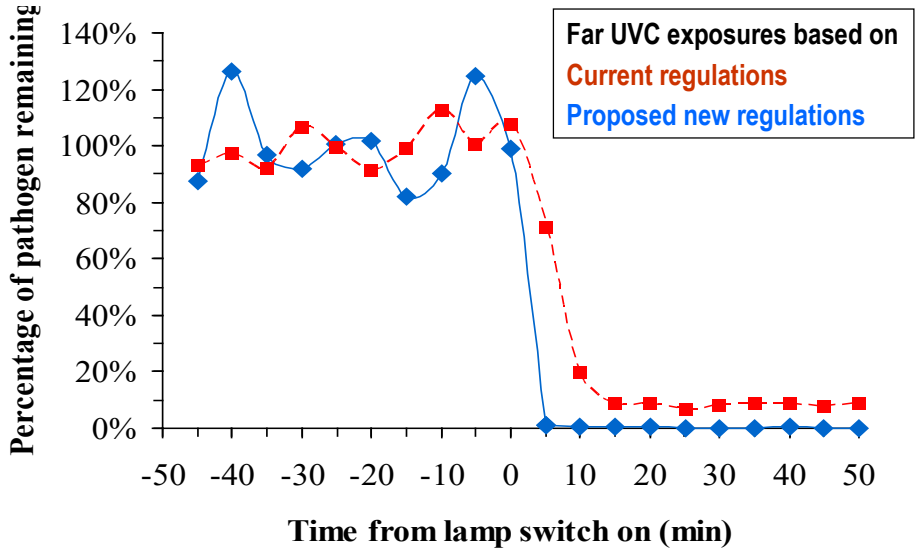
Far-UVC inactivation of aerosolized viruses and bacteria





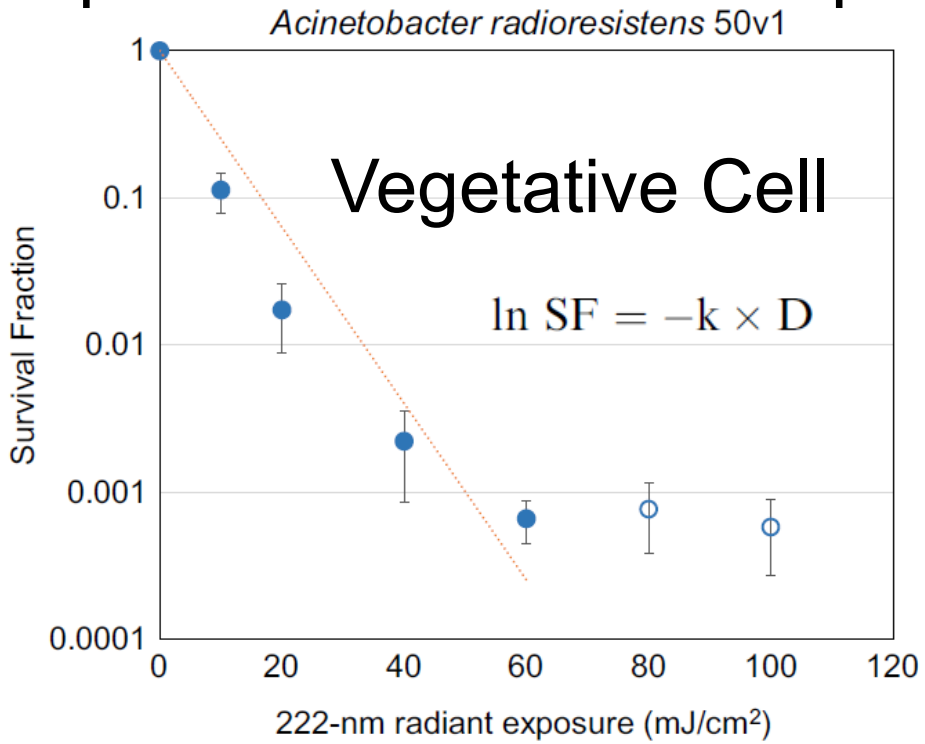






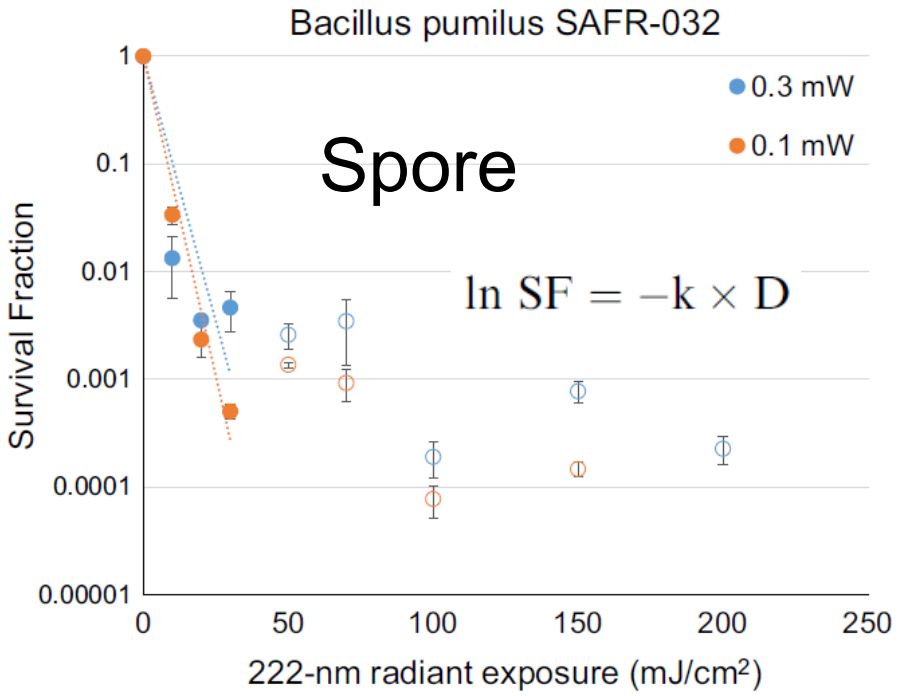
Far-UVC efficiently inactivates bacteria on surfaces

- Expose on aluminum coupons using a filtered KrCl lamp (222 nm)



$k = 0.14\ cm^2/mJ$

$D_{90} = 16.9\ mJ/cm^2$



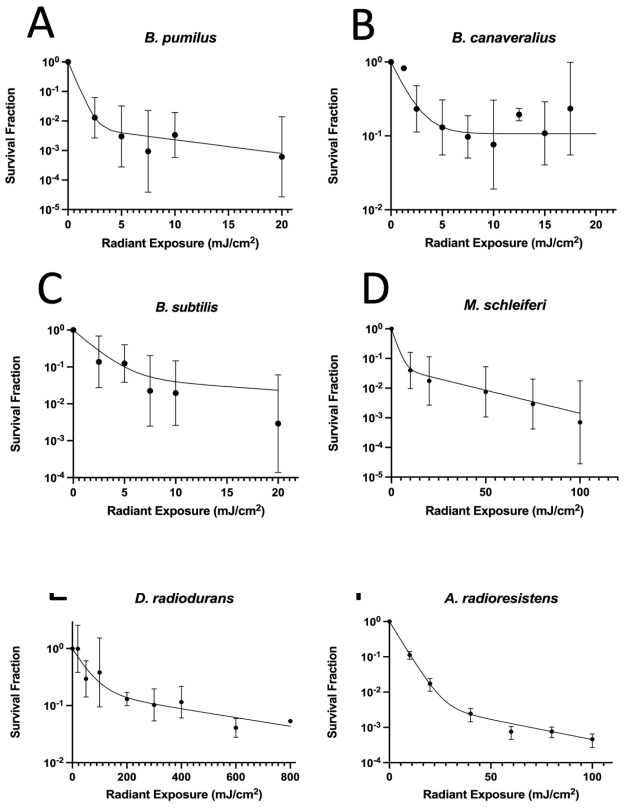
$k = 0.23\ cm^2/mJ$

$D_{90} = 10.2\ mJ/cm^2$

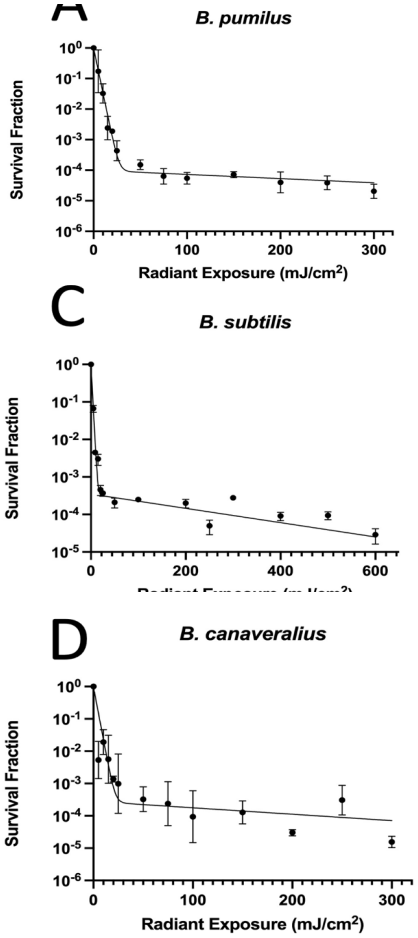
Seuylemezian, Arman, et al. "Far-UVC light as a new tool to reduce microbial burden during spacecraft assembly." *Advances in Space Research* 67.1 (2021): 496-503.

Far-UVC efficacy

- Vegetative Cells



- Spores

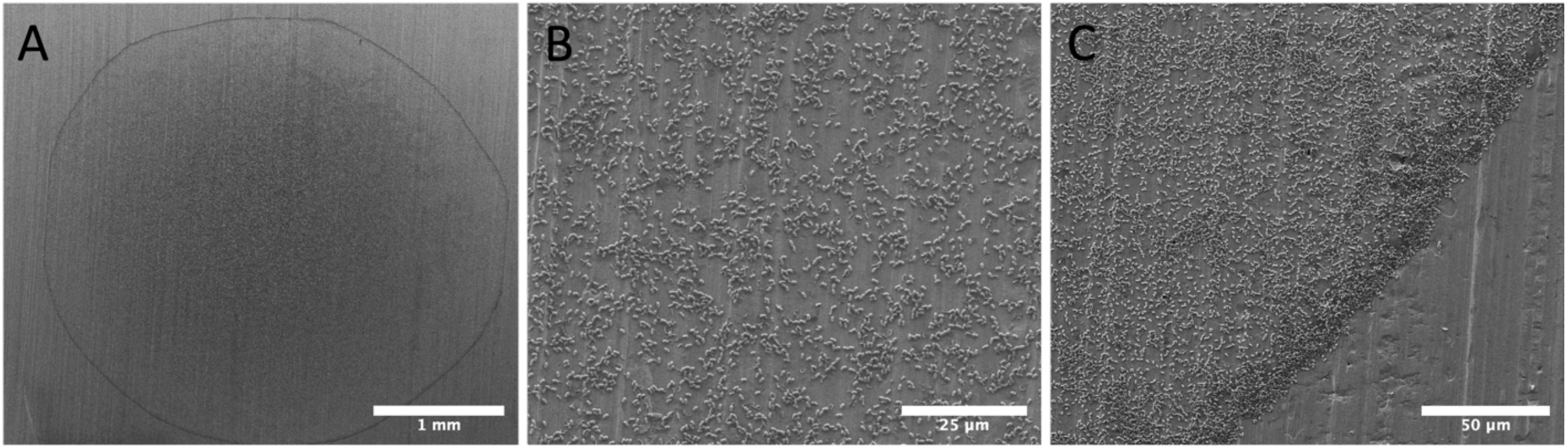


$$S = (1 - f)\, e^{-k_1 D} + f e^{-k_2 D}$$

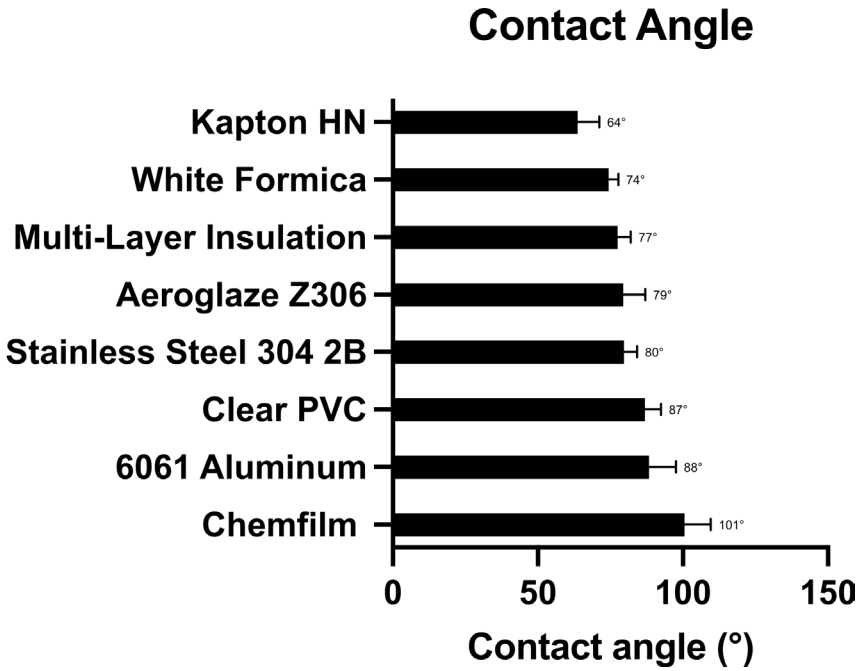
Species	Cell type	$k_1 \pm$ SE (cm^2/mJ)	$k_2 \pm$ SE (cm^2/mJ)	D_{90} (mJ/cm^2)	f ± SE
B. pumilus	Vegetative	1.9 ± 6.8	0.11 ± 0.099	1.2	$6.8\times10^{-3} \pm 7.6\times10^{-3}$
B. canaveralius	Vegetative	0.72 ± 0.54	0.0 ± 0.038	3.2	0.11 ± 0.12
B. subtilis	Spore	0.54 ± 0.031	$4.4\times10^{-3} \pm 5.5\times10^{-4}$	3.8	$3.5\times10^{-4} \pm 7.0\times10^{-5}$
B. subtilis	Vegetative	0.57 ± 0.23	0.045 ± 0.14	4.0	0.058 ± 0.10
M. schleiferi	Vegetative	0.45 ± 0.42	0.036 ± 0.013	5.1	0.051 ± 0.046
†*B. pumilus*	Spore	0.48 ± 0.070	$0.016 \pm 2.5\times10^{-3}$	5.9	$6.3\times10^{-3} \pm 1.7\times10^{-3}$
B. canaveralius	Spore	0.38 ± 0.045	$4.6\times10^{-3} \pm 1.7\times10^{-3}$	6.1	$2.8\times10^{-4} \pm 1.3\times10^{-4}$
B. pumilus	Spore	0.34 ± 0.015	$3.2\times10^{-3} \pm 6.1\times10^{-3}$	6.8	$1.0\times10^{-4} \pm 2.0\times10^{-5}$
†*A. radioresistens*	Vegetative	$0.22 \pm 3.3\times10^{-3}$	$0.026 \pm 1.4\times10^{-3}$	11	$6.1\times10^{-3} \pm 6.9\times10^{-4}$
D. radiodurans	Vegetative	$0.021 \pm 7.2\times10^{-3}$	$1.8\times10^{-3} \pm 1.0\times10^{-3}$	112	0.18 ± 0.097

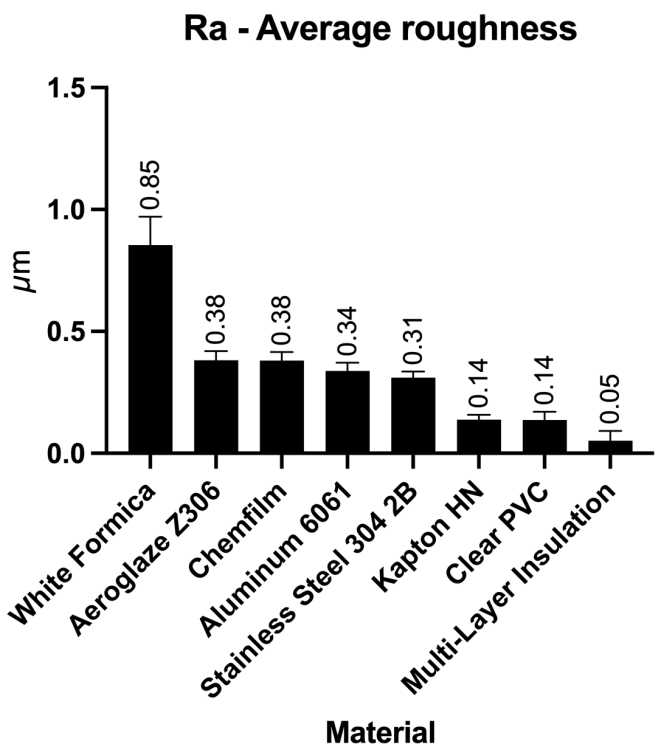
Petersen, Camryn, et al. "Susceptibility of extremophiles to far-UVC light for bioburden reduction in spacecraft assembly facilities." *Life Sciences in Space Research* 41 (2024): 56-63.

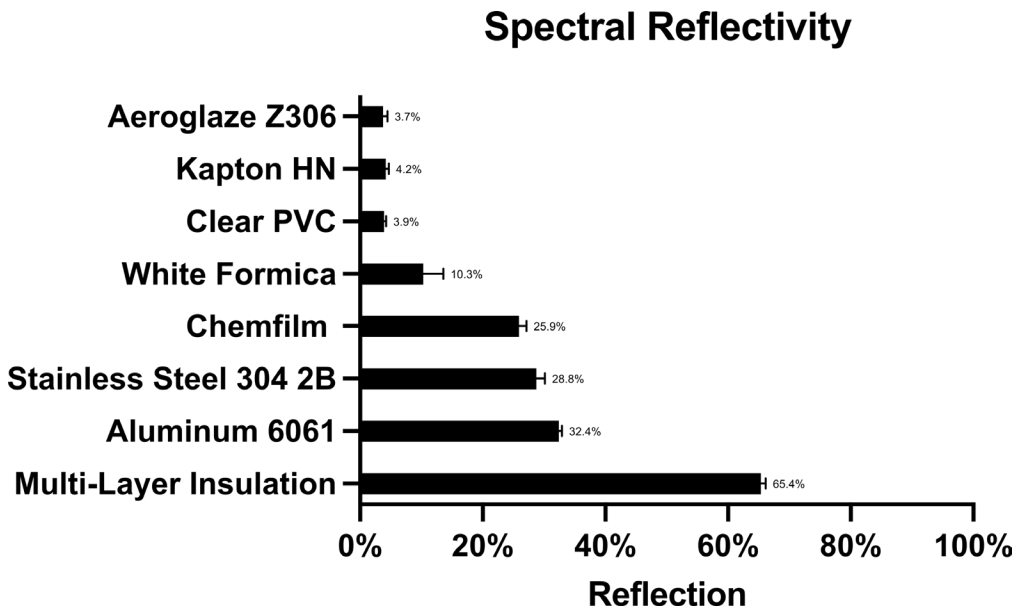
SEM images of spore exposure condition



Exploring material effects

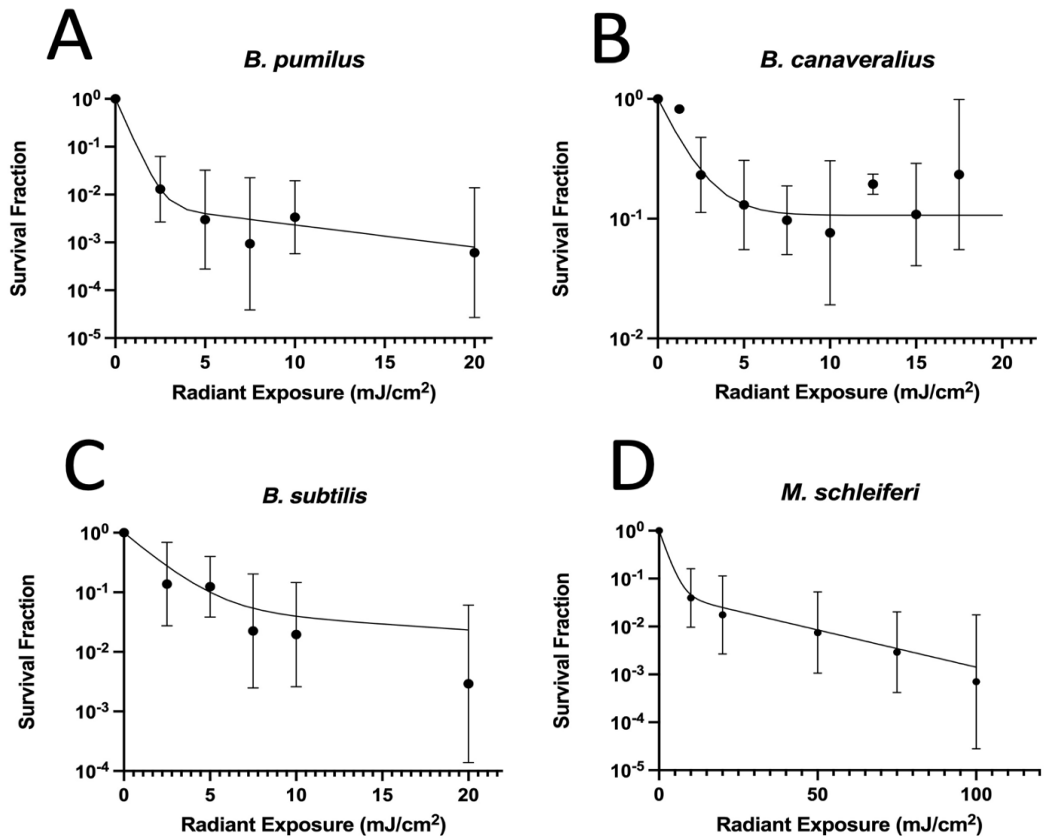






Next Steps

- Improving testing to eliminate tailing effects
  - Better understanding of true susceptibility
  - Better simulation of realistic exposures within cleanrooms



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Questions?