APPLICATION BRIEF

UV DISINFECTING SYSTEM FOR AIRCRAFT CABINS

The current global pandemic caused by COVID-19 has impacted people around the world and has caused many industries to come to a halt because of the risks of transmission. Due to the way the virus is transmitted and its ability to survive on surfaces for an extended period of time, there is a strong need for ensuring proper cleaning and disinfection of frequently visited areas. This is particularly important for the transportation industry (air, rail, subway, etc.), where seating and support structures are shared among many travelers, with little possibility of avoiding contact. In order to begin re-opening these methods of transportation at scale, the public needs to have confidence that these environments are safe.

To maximize their return on investment, it is important that transportation vehicles minimize their time at the gate or station, which requires a quick cleaning process for the cabin. At the same time, a thorough cleaning of the cabin is crucial to convince passengers that the risk of being contaminated while traveling is minimal. These apparently conflicting goals — quick and thorough — cannot be achieved using traditional approaches. An innovative technology has proved to be efficient in quickly decontaminating hospital rooms using a high dosage of ultraviolet (UV) light on all potentially contaminated surfaces. Supplementing, or potentially replacing, manual cleaning of surfaces with an automatic and faster UV light treatment system can increase the certainty that any virus present is deactivated.

Simulation can be used to design the right UV light treatment system for each environment and for validating that sufficient doses of UV light are being delivered to ensure virus deactivation.

/ Challenges

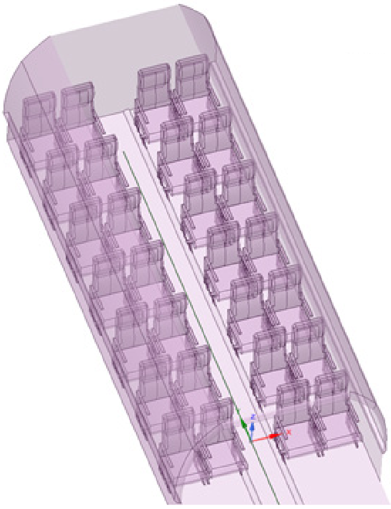
Many challenges must be overcome to design and deploy the optimal UV light treatment system for a given environment:

1. Choosing the optimal lighting system. Mercury vapor lamps, operating around 250 nm in a wavelength band known as UV-C, are currently the most common lamps for disinfection purposes. Higher wavelengths, for example UV-B sources around 300 nm, are not as effective and present higher risk in cases of accidental exposure to the UV light. Lower wavelengths, for example sources around 200 nm, can be more effective, but they can create ozone that would need to be removed from the transportation environment. There is also active research into improving the efficiency of LED-based systems operating at these wavelengths.

2. Choosing (and optimizing) the light delivery system. The two main possibilities here are installing light fixtures or using a mobile (autonomous) solution. Installed fixtures can be quickly and easily activated but require significant remodeling (potentially cost/time-prohibitive) and may not deliver the UV light efficiently to all surfaces in the environment. An autonomous mobile system, on the other hand, can cover all the surfaces more efficiently, but an added complication is that it must enter/exit for each cleaning. It also presents additional challenges with regards to navigating around the environment.

3. Ensuring complete exposure and irradiation of all relevant surfaces. UV light disinfection systems operate on the principle of "line of sight"; for a surface to be disinfected, it needs to be directly within sight of the light source. Any shadows caused by occluding objects can cause incomplete coverage of the environment.

4. Understanding the dosage requirements. The target dosage for the COVID-19 virus is approximately 600 μJ/cm^2. Based on the output power of the UV system, this translates directly into an exposure time (e.g., duration that the system needs to be turned on), or a motion speed (e.g., how slowly the mobile system needs to move).



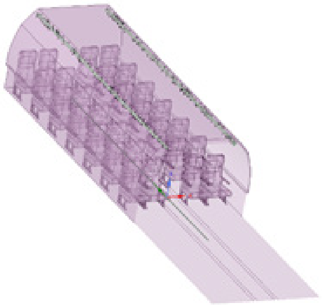
Solution

Ansys simulation tools can be used to solve the challenges of designing and deploying a UV light treatment system. Ansys SpaceClaim quickly creates a 3D mockup of the environment under test (train carriage, airplane cabin, etc.). Assets, such as a cleaning robot, can be added with ease, as well as the trajectories of any dynamic assets. Ansys SPEOS applies optical reflectivity properties to the different objects; creates the source model with specific output power, spectrum and distribution; and simulates the total irradiation incident on all surfaces. This includes light bouncing off objects (e.g., when bouncing off a highly reflective object, a ray will carry its energy to the next object), as well as shadows created from line-of-sight issues. Irradiation on curved surfaces can also be accurately captured, as the powerful 3D sensor maps the detectors directly to the object mesh. Finally, the worst-case exposure requirements can be determined by evaluating the surfaces with the smallest cumulative irradiation.

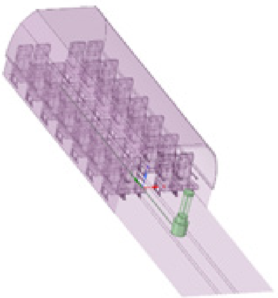
The presented case study for an airplane cabin interior compares the effectiveness of installed UV light fixtures with two different autonomous robot solutions. The cabin walls are assumed to have a highly reflective white paint (80% reflectivity) applied and in all cases the total output power is 100 W at 253.7 nm. Clearly, the design of the robot delivery system can have a large impact on the irradiation coverage within the environment. Also, in this case the installed fixtures and the optimized mobile solution have similar performance, although the installed fixtures are highly idealized.

Case Study – Airplane Cabin Example

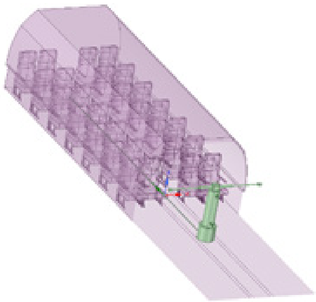
The first set of images show the 3D model of a single aisle/4 seats per row airplane cabin, which is commonly used for relatively short flights for which reducing the time at the gate is essential. The motion path for the UV robot is included in the computer model.



Airplane cabin 3D model with installed UV-C light fixtures.

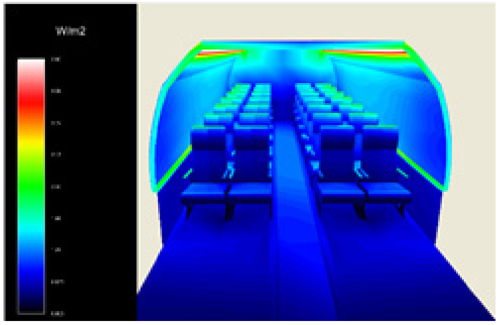


Airplane cabin 3D model with original UV-C robot design.

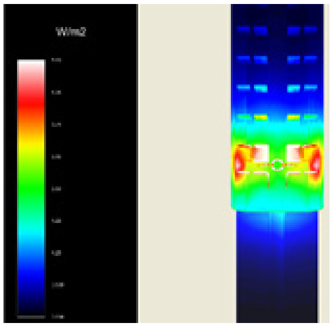


Airplane cabin 3D model with optimized UV-C robot design.

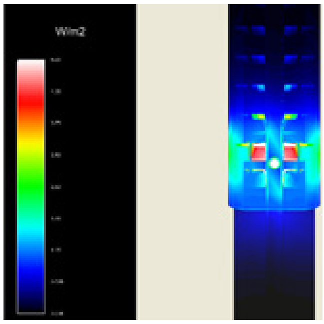
The second set of images quantify the irradiation coverage (W/m^2) of the cabin interior using the different solutions (robot designs and installed UV-C light fixtures). Brighter colors indicate high irradiation, while darker colors indicate lower irradiation. The left figure illustrates that the installed UV-C light fixtures cover all the seats but struggle to deliver the necessary irradiation coverage to all surfaces. The middle and right figures are related to the moving robot solution. It's clear to see the benefit of the second robot design (with arms stretched above the seats) compared to the first design.



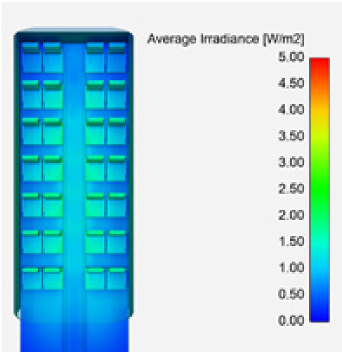
Irradiation (W/m^2) snapshot of cabin interior using UVC light fixtures.



Irradiation (W/m^2) snapshot of cabin interior using original robot design.

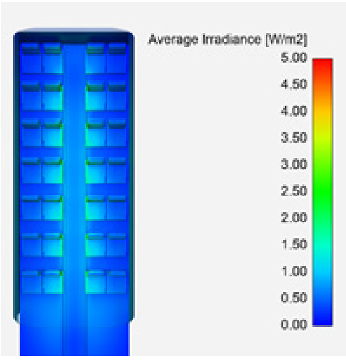


Irradiation (W/m^2) snapshot of cabin interior using optimized robot design.



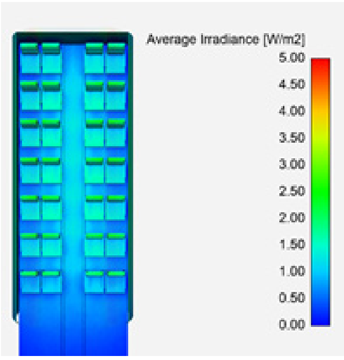
Cumulative irradiation (W/m2) on cabin interior using light fixtures.

Time required to obtain 600 μJ/cm² dosage across all surfaces: 150s.



Cumulative irradiation (W/m2) on cabin interior using original robot design.

Time required to obtain 600 μJ/cm² dosage across all surfaces: 600s.



Cumulative irradiation (W/m2) on cabin interior using optimized robot design.

Time require to obtain 600 μJ/cm² dosage across all surfaces: 100s.

The third set of images integrate the total irradiation on all surfaces across the entire motion path to calculate the necessary exposure to reach the 600 μJ/cm² requirement. The optimized robot design is 6X better than the non-optimized design and is slightly better than the installed fixture approach. These exposure times enable us to calculate the robot's necessary motion speed (0.21 m/s for design 2, and 0.034 m/s for design 1).

/ Conclusion

Optical modeling demonstrates that it is possible to use different methods to deliver the necessary UV light dosage of 600 μJ/cm² to all surfaces of the cabin potentially in contact with passengers. Of the three configurations, the moving robot with stretched arms (design 2) is the most likely to guarantee that the correct UV light dosage is delivered. This original decontamination approach could disinfect an airplane in a few minutes while it is stationary at the gate.

/ Reference:

1. "These virus-fighting robots are being used to disinfect hospitals", CNBC Outbreak, Feb 5, 2020

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