PROFESSOR: So now that we have a fully parameterized safety guideline for indoor spaces to limit the transmission of COVID-19, we can go through some case studies.

And I encourage you to use the guideline, in the form of the spreadsheet or the online app which are provided, to check out your own space to see how you might mitigate transmission there.

So here are two representative examples of great interest today.

So the first is a classroom in the United States, which is very relevant for discussions about closing or reopening or partially reopening our schools during the pandemic.

And the second example will be that of a nursing home, which is a tragic situation of great interest, because a large fraction-- in fact, almost half-- of all deaths have occurred in nursing homes and eldercare facilities here in the United States, and a very significant number around the world.

So first, let's look at the classroom case.

So if we apply the guideline, first of all, we see the typical shape of what is predicted in a plot of occupancy versus time, which is a curve with roughly a 1 over x type behavior, because it is the product of occupancy and time essentially that are limited by the guideline.

So you trade one for the other.

So we have here curves representing natural ventilation, which we estimate to be an air change time of around 3 per hour-- or 0.3.

Excuse me-- so a 3-hour air change time, and also mechanical ventilation, in this case with 8 air changes per hour, so reasonably good mechanical ventilation, which is the red curve-- the blue curve being the natural.

And this is in a typical classroom space of 900 square feet and 12-foot-high ceilings, so for the United States.

And in such spaces, the typical occupancy might be around 20 or 25 students.

And so 20 students is actually indicated here as the normal occupancy for this space.

And so what we see is that the normal occupancy is safe for a certain amount of time.

But then eventually, it becomes unsafe.

And so in the case of lower ventilation, of course, that transition happens more-- sooner.

And if you have better ventilation, you can extend that time.

Also in the dotted line here is shown the transient solution in the guideline, which accounts for the buildup of infectious aerosols when an infected person first enters the space.

And you can see in this case, that buys you just a little bit of extra time only in the case of the natural ventilation, but really not much in the case of mechanical ventilation, where the transient and steady state curve essentially overlap.

We can also compare this with some typical official guidelines here in the United States and also elsewhere.

So first, we have the 6-foot rule.

And what we see is that after a fairly short time, the 6-foot rule becomes inadequate in the case of natural ventilation.

In the case of mechanical ventilation, still at some point, the 6-foot rule is unsafe.

However, before that transition happens, it's actually overkill.

So for enforcing the 6-foot rule, we are keeping people at a fairly low density when perhaps that's not necessary for airborne transmission, especially if masks are being worn, because that cuts down the short-range transmission and droplet transmission that we've discussed.

And airborne transmission, analyzed by the guideline, is expected to be the dominant mode of transmission.

So the way this plot is made is also allowing for rescaling by the use of masks.

So and also, by-- so that's the horizontal axis.

So what is plotted here is the mask-adjusted time, which is pm squared times tau.

So pm is the masked transmission factor.

So a very good mask has pm near 0-- for example, maybe 0.05 or even 0.01 for a good surgical mask, maybe 50% or 30% for a decent cloth face covering.

And so that comes in squared.

And that factor rescales the time.

So for example, we see here with ventilation, we might expect to get 40 hours in this case with the 6-foot rule, or if we're at normal occupancy, maybe 20 hours.

But if we have good masks that have pm squared maybe on the order of 100, let's say, or even 1,000-- so depending on what that value is-- you see you can turn that 20 hours into thousands of hours.

And so it actually becomes quite safe to stay in that space.

Now, on the vertical axis, we have the occupancy limit scaled by epsilon, the risk tolerance.

So what's shown here, then, is effectively risk tolerance of 1, which we would not want.

We don't want any transmissions.

But if you reduce that to epsilon of 0.1 or even 0.01, then you again pick up a factor of, let's say, 10 to 100 reduction in the time or the occupancy.

But again, with masks, that's offset by a factor which is typically larger than that.

So what we're seeing here is that even in a very conservative viewpoint, if we analyze a classroom space-- where there by the way is no filtration or other mitigation measures occurring except for ventilation at either of these rates-- we see that if masks are worn consistently that we should be able to get tens or even hundreds of hours of shared use of that space, even at normal occupancy.

Now, how should we interpret that time?

So the time could be a continuous occupancy time.

But especially if we're looking at the steady state value, which is more conservative than the transient, then we can simply add up the cumulative time that people spend together in the presence of an infected person.

And so if we get to a number like, for example, 40 hours, which we can easily achieve wearing masks with normal occupancy and decent ventilation, then that might correspond to one week in the classroom with an infected person.

That's a very good number, because the time to symptoms is around five or six days with COVID-19.

Now, of course, some transitions may be symptomless.

But the recovery time is also on the order of maybe two weeks.

And so if you can stay during that period of time in the presence of an infected person, that infected person essentially will be removed, either by recovery or by showing symptoms and hopefully removing themselves and going home.

Also, this kind of analysis can inform testing.

If the guideline says that you're safe for a week or even two weeks of occupancy, given the number of hours per day and the other conditions, and the testing frequency is, let's say, once per week-- and also we know that the most infectious time only happens after, say, five or six days after becoming infected-- then with weekly testing and mask use, this becomes an extremely safe situation from the perspective of airborne transmission if people are wearing masks carefully during that time.

So that's one way to think about these guidelines.

Also, the guideline can tell you the relative risk improvement if you, say, introduce filtration, or you change the humidity of the room or change the ventilation rate other than values shown here.

And you can play with the spreadsheet or the online app to see how those changes can take place.

Our next example is a nursing home.

Now, here, I've-- instead of scaling to epsilon, the risk tolerance, I've just chosen a risk tolerance of 0.01, which is a 1% risk of transmission if an infected person were to enter this space.

You may want to take even a smaller value, to be even more conservative, given the grave danger that persons who are in nursing homes are facing, partly due to their age and also due to the common situation of pre-existing conditions, given that in many cases, there may only be months or years left of life expectancy for those people.

And so they are, in fact, at the highest risk for COVID-19.

So you want to pick a very small epsilon.

And so now, if you look at these curves, then you see the horizontal axis has now changed to minutes.

So that's if no one is wearing a mask, then on the order of minutes-- so something like the 15-minute rule-- you can see there becomes a risk of infection, although ventilation can help and can turn the 15 minutes, say, into 30 minutes.

If we look at, say, the 6-foot rule, which is shown here, which would only place two people in a typical nursing home room that we have just shown here-- so that would be two beds, although in some cases, as in the example shown here, which is based on New York City nursing homes, the size of the space that we've assumed here would actually have a normal maximum occupancy of three.

So there could even be three beds in this space.

And the point is that even if these beds are 6 feet apart, if the people are not wearing masks-- or if a person enters the room, who is infected, who is not wearing a mask-- the risk of transmission is actually very high.

And if people spend long periods of time without masks, as many nursing home patients must do because they have trouble breathing already-- so unless they're on a respirator, if they're just kind of in relatively good shape, they will be breathing oftentimes for long periods without masks.

And that can be a serious problem and lead to very high risk.

So the guideline essentially helps to sound the alarm for those sorts of situations and helps those facilities and the caregivers design the space and the time spent in the space with different people in a way that can help to protect the residents, and also when combined with testing and other mitigation measures, can hopefully reduce the spread of the disease where it matters the most and has led to the most deaths.