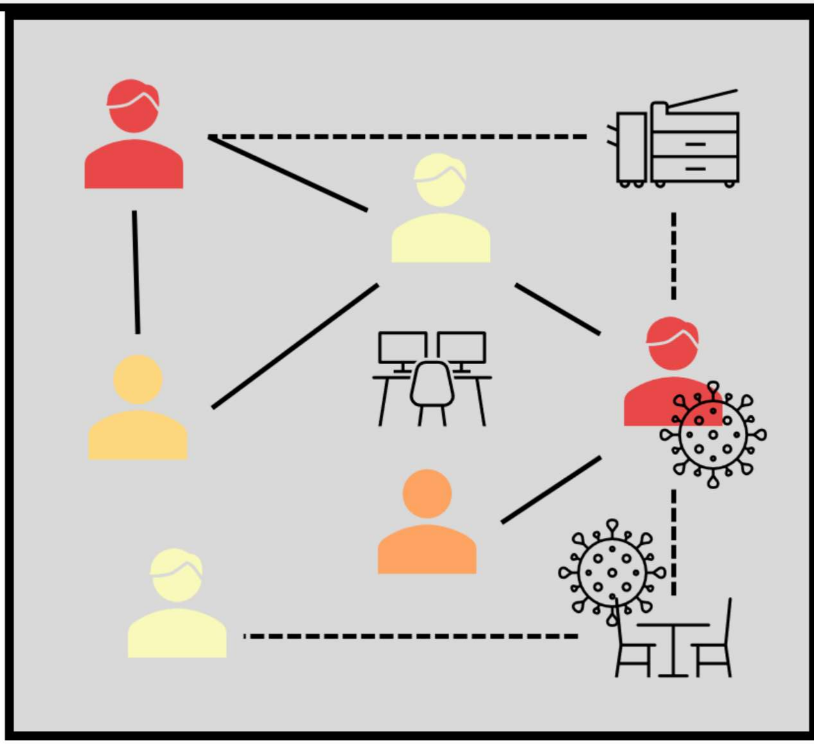
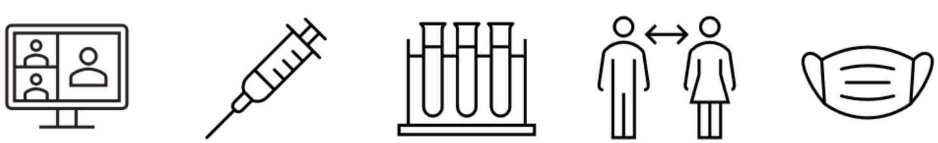
Integrating COVID-19 Models at Different Scales for Infection Risk Estimation and Control Optimization

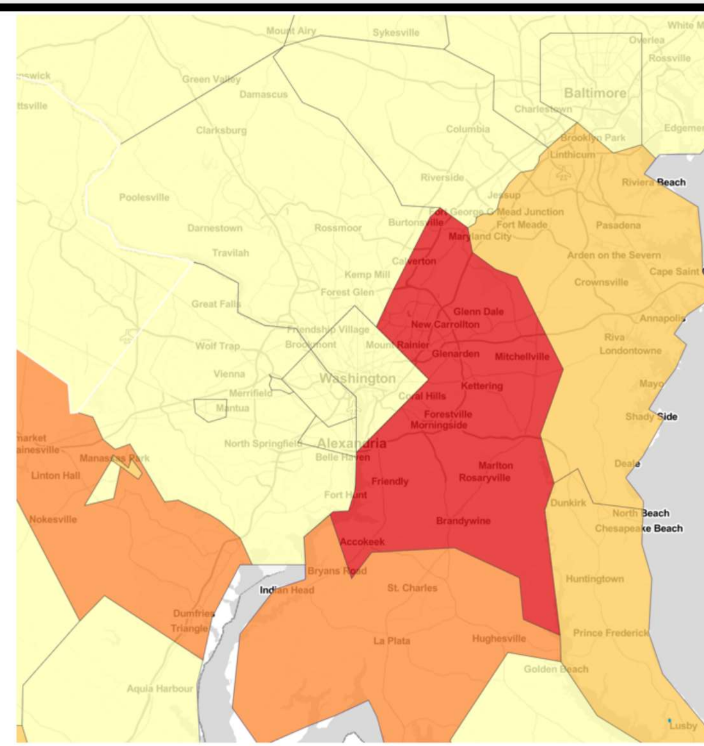
Collin Schwantes, Benno Lee, Marjorie Willner, Ben Ortiz, Viveca Pabon-Harr

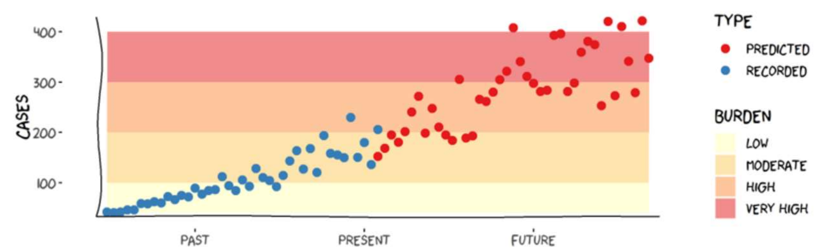
Introduction



Probability of Infection Modifiers







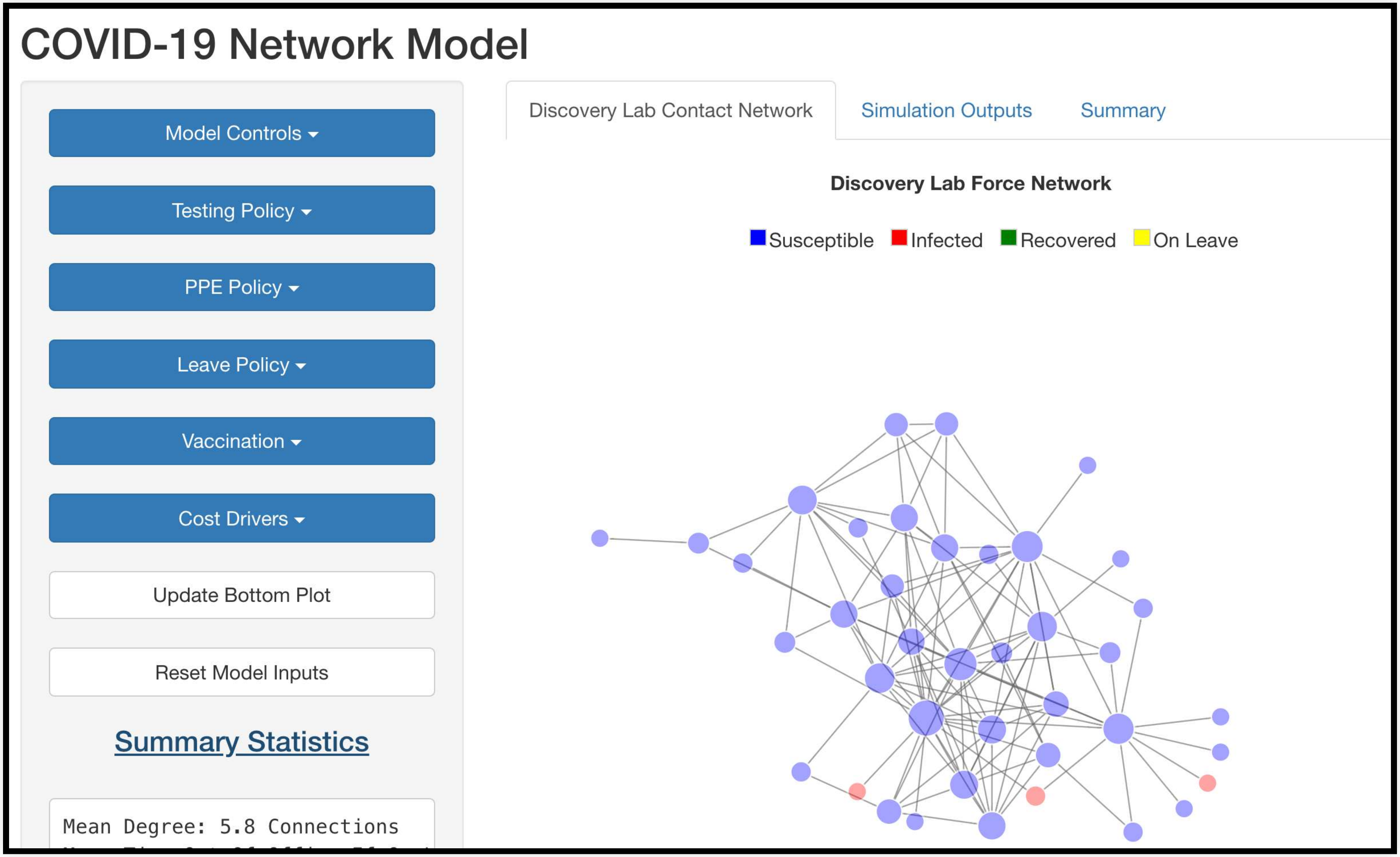
The system is complex

- Processes are non-linear
- Policies outside your institution impact outcomes in your institution
- Systems within your institution interact in unexpected ways

Problem Statement

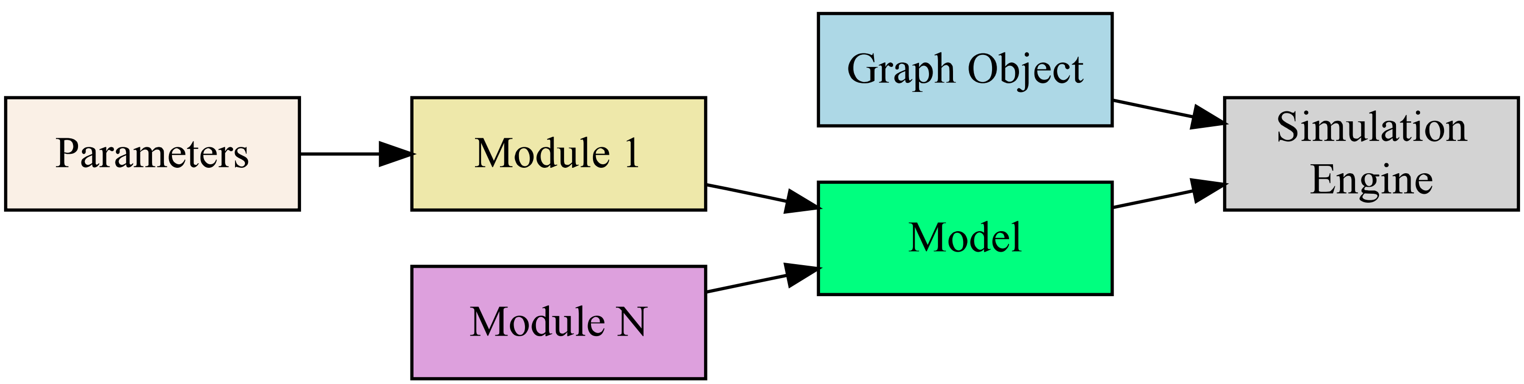
Assessing risk of SARS-COV-2 infection in indoor spaces is complicated because interactions at multiple spatial and temporal scales influence fine scale disease transmission.

Graphical User Interface

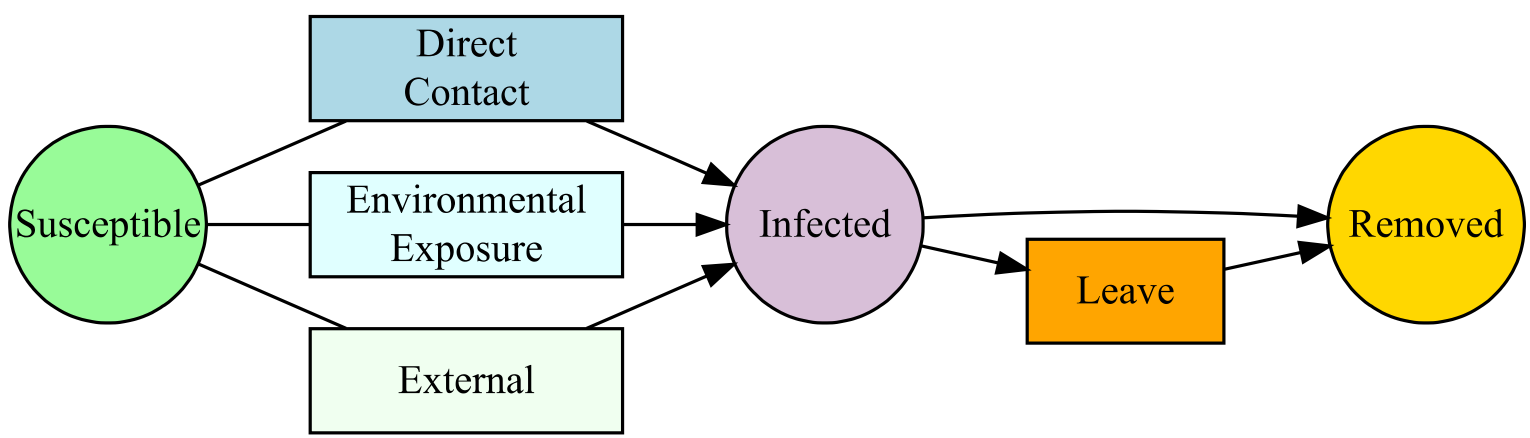


Simulation Framework

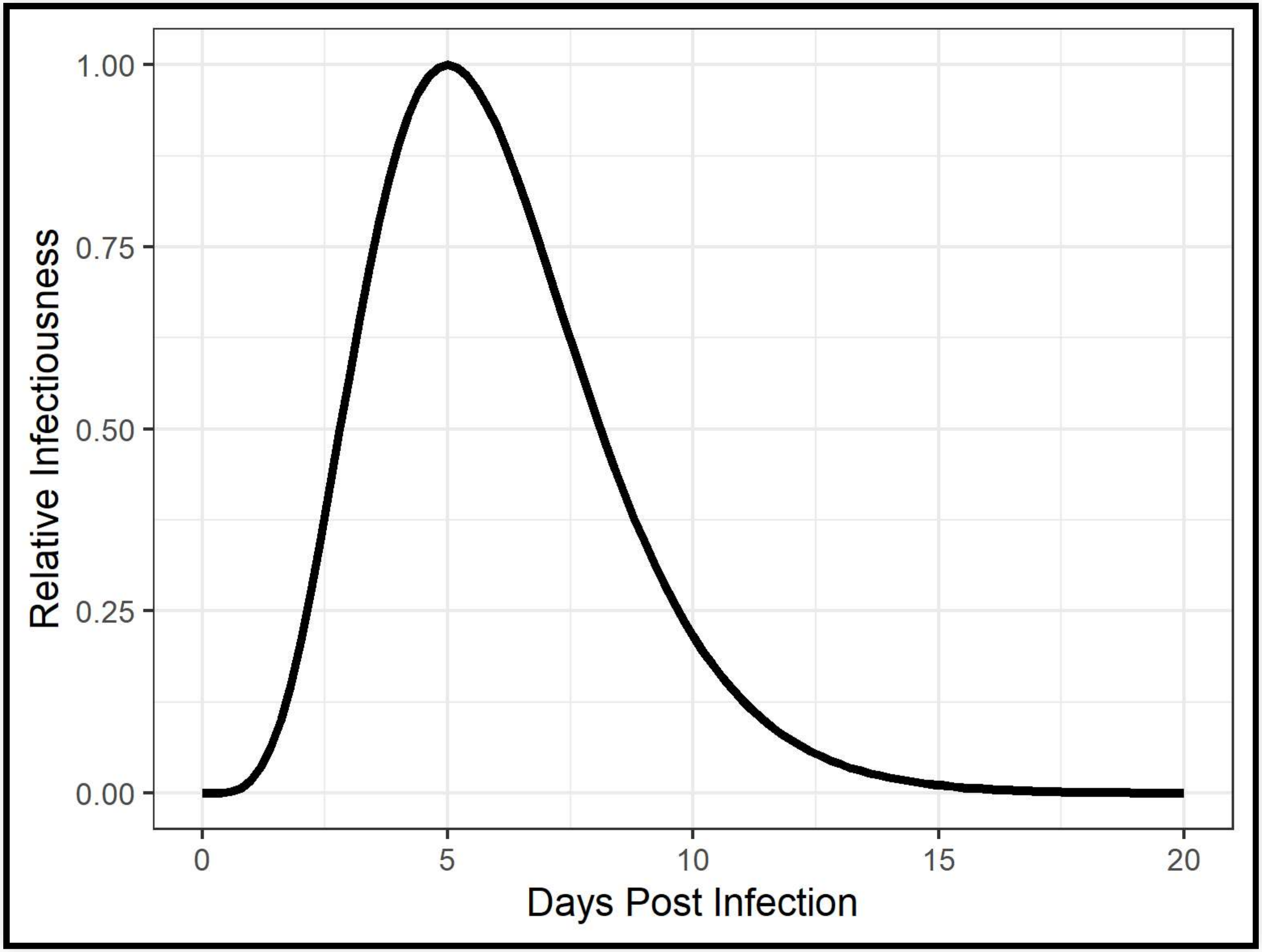
We developed extensible simulation engine accepts modules that modify transmission dynamics.



Extended SIR Model



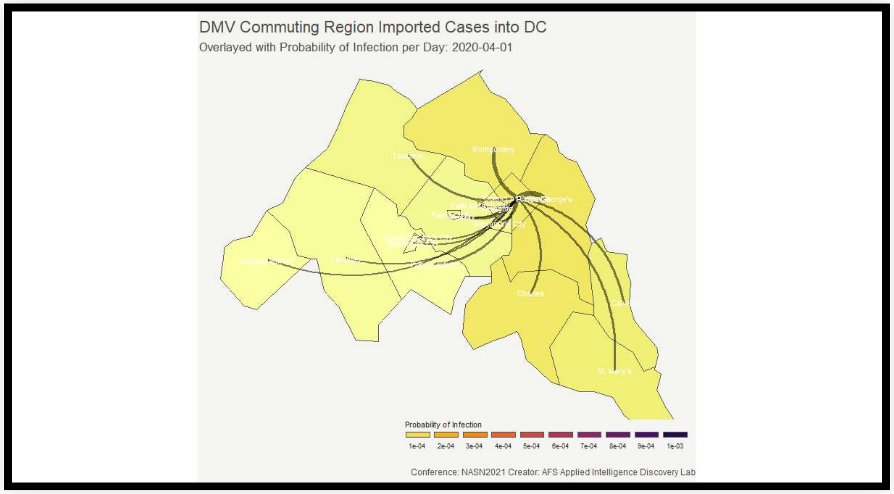
Infectiousness Profile



How does transmission happen in our Model?

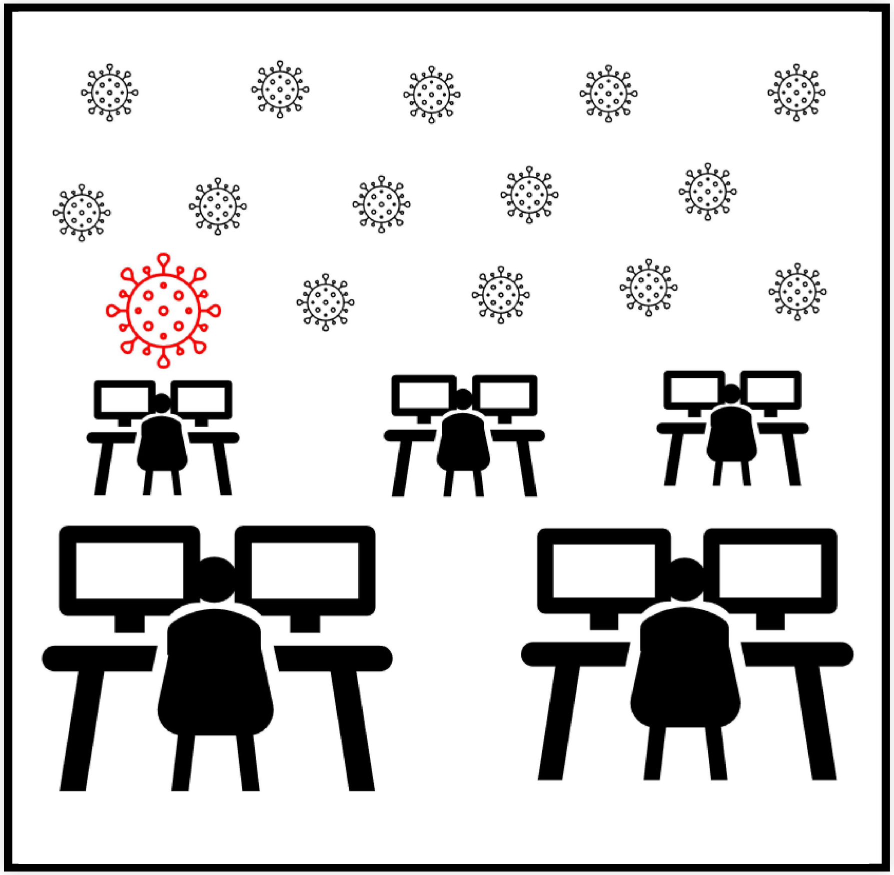
1. External Transmission
2. Environmental Transmission
3. Direct Contact Transmission

Estimating external infections



- External infections are derived from a micro markov process model that explicitly incorporates mobility metrics and imported cases

Estimating Environmental infections

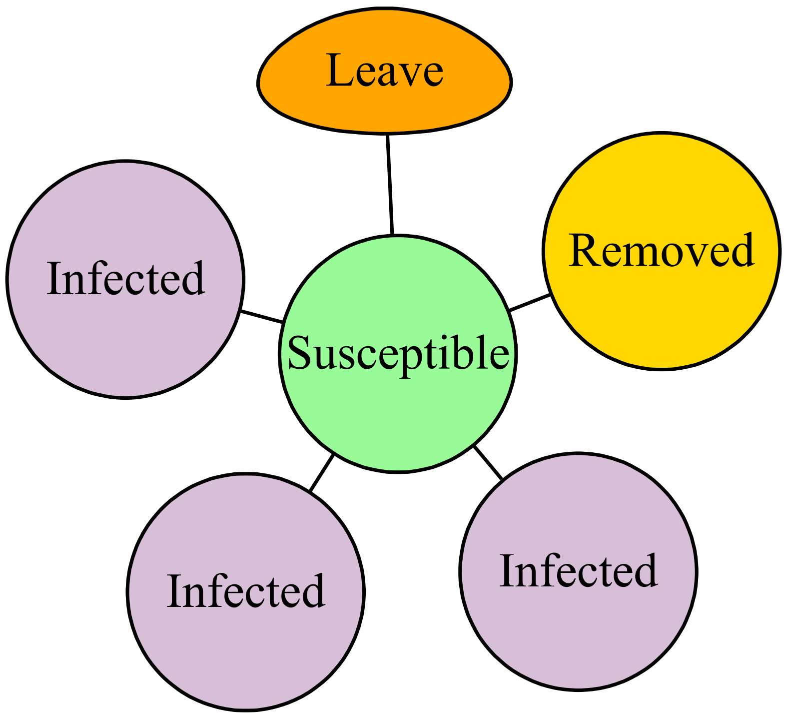


Risk of Infection

- *Emission Rate*
- *Viral Concentration in Room*
- *Inhalataion Rate*
- Time divided into 15 minute segments

G. Buonanno et al. 2020

Estimating direct contact infections



$$R_j = \sum_{i=1}^{n} I_i \delta_i P_{dc}$$

I_i = relative infectiousness of adjacent infected nodes

δ_i = transmission modifiers

P_{dc} = probability of infection given direct contact

How is transmission prevented?

Hierarchy of Controls

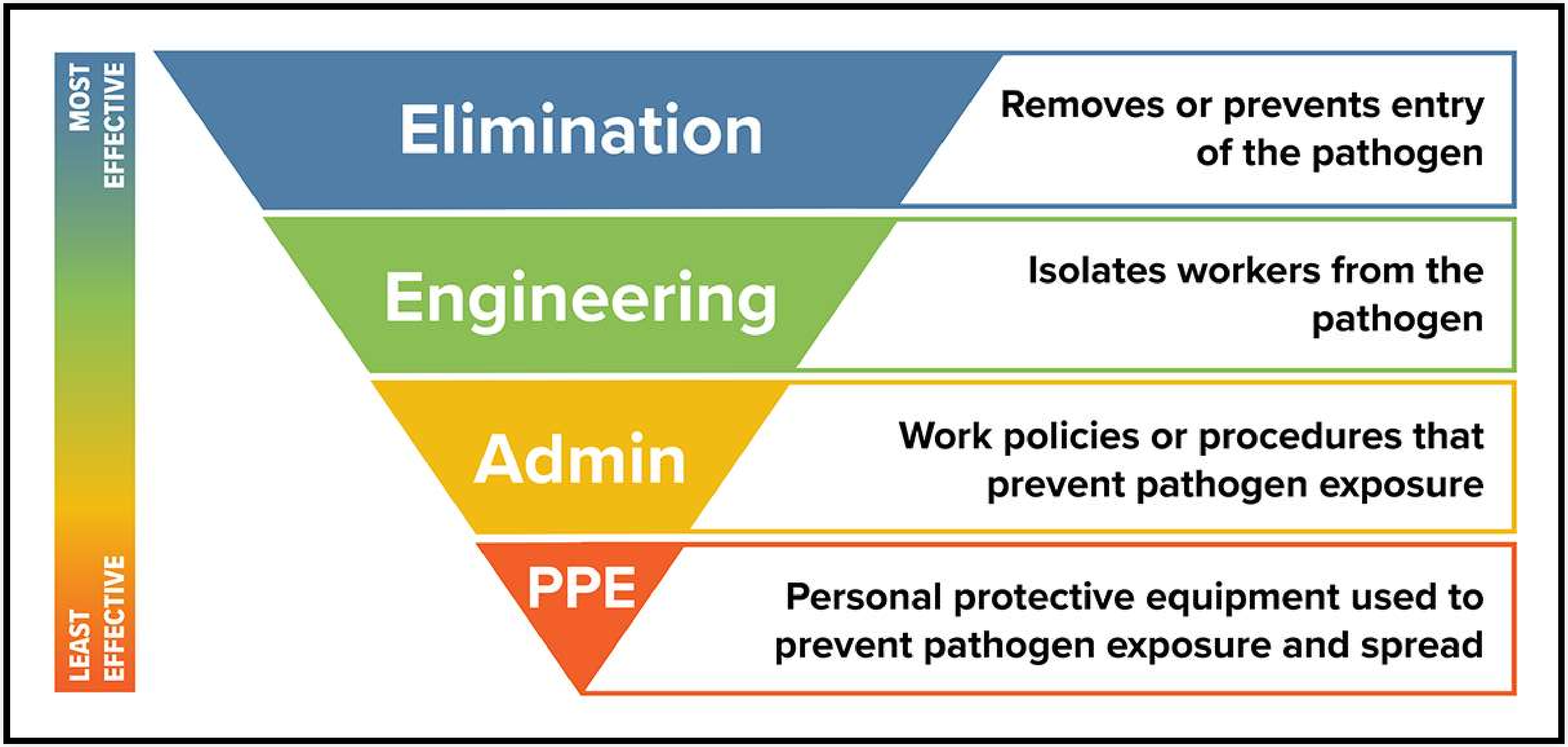


Image produced by University of California Davis

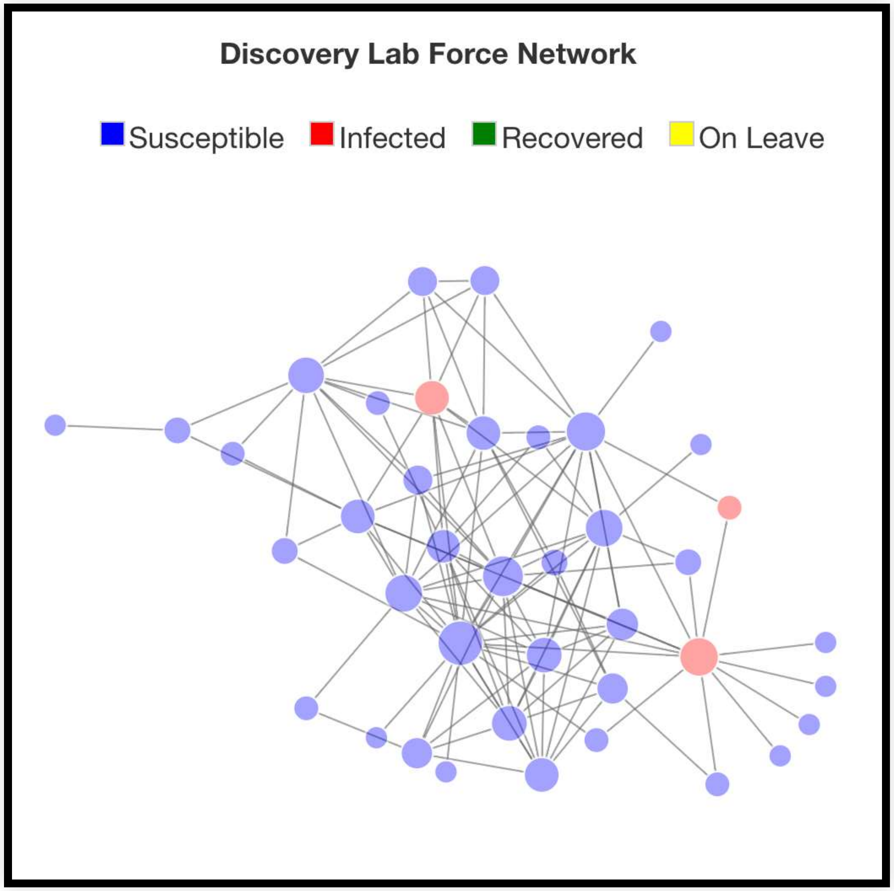
Hazard Control modules

- **Leave Policy** - removes individuals who tested positive for a number of time steps
- **Room Density Limits** - reduces number of people in a room
- **Personal Protective Equipment** - reduces the probability of acquiring infection
- **Testing** - does not directly impact transmission but may inform other policies (e.g. leave)

Vaccination

- Protects from severe disease
- May not prevent transmission

Data Collection

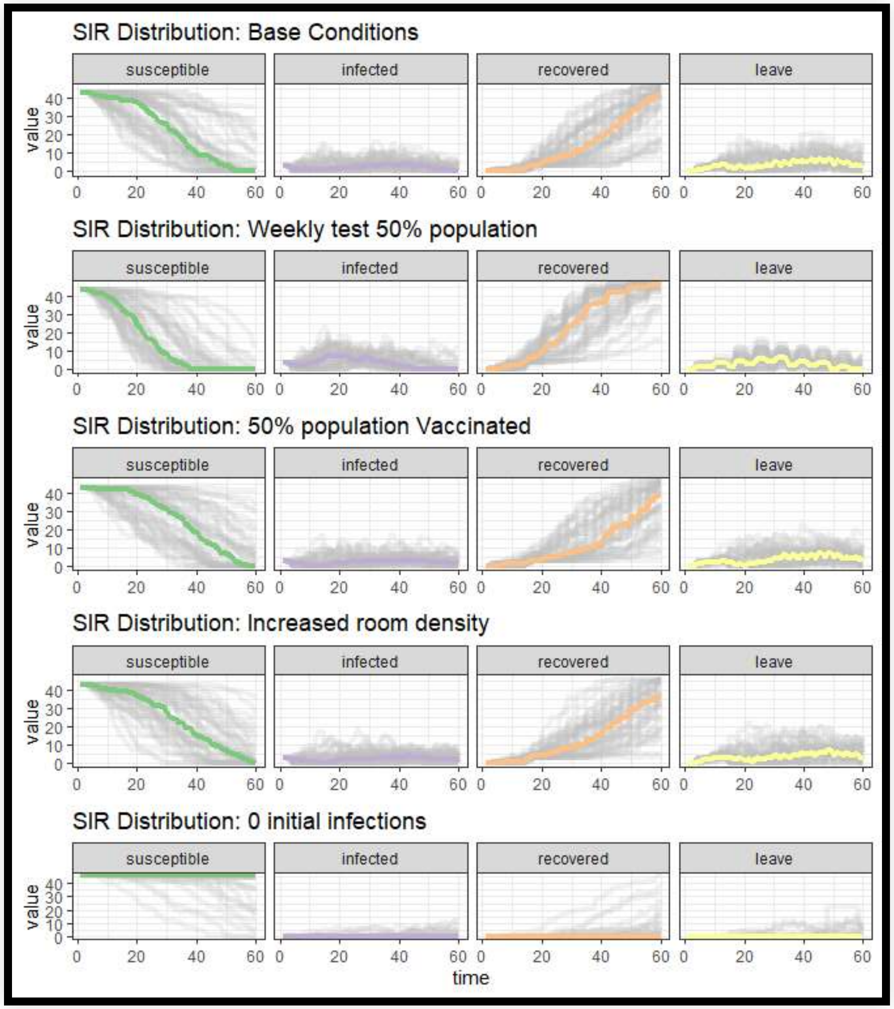


- Surveyed lab mates asking them to indentify contacts (n=46)
- Took mean of reported contact strength
- Estimated room volumes
- Other values derived from literature

Model Initial Conditions

- Three random infections
- Testing occurs every three days, 50% of population is tested and receives results within two days.
- 95% of people using full PPE suite (surgical mask, eye protection, distancing)
- Density limit of $\frac{1\,person}{12\,m^3}$
- 100 simulation runs, 60 time steps each
- Other parameters determined by exhaustive lit review (see table in appendix)

Results



- Testing frequency and leave policy have greatest impact on transmission
- Increasing room density increases transmission
- Direct contact and environmental transmission are the primary transmission modes

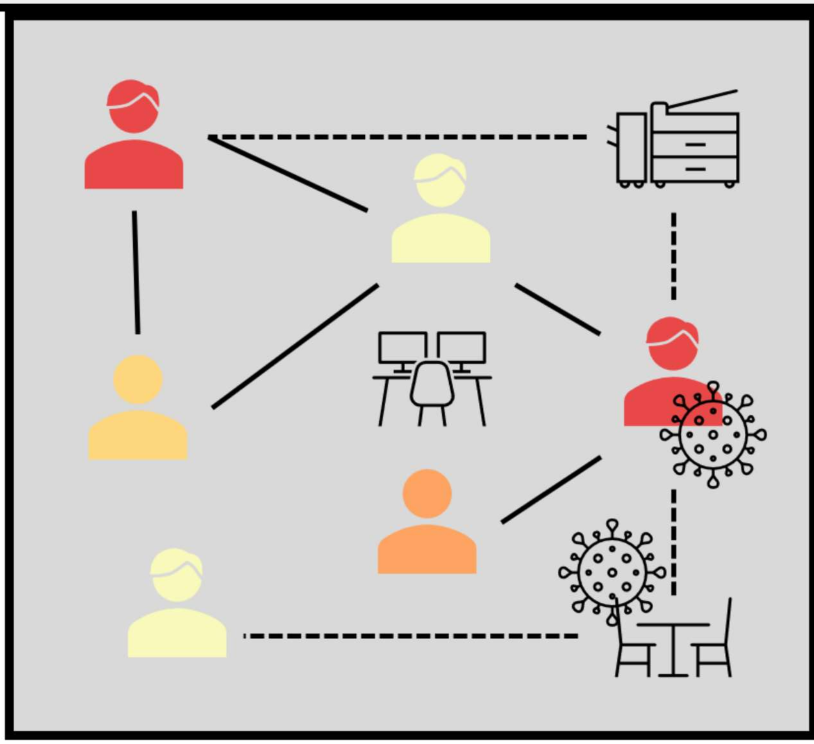
Conclusions

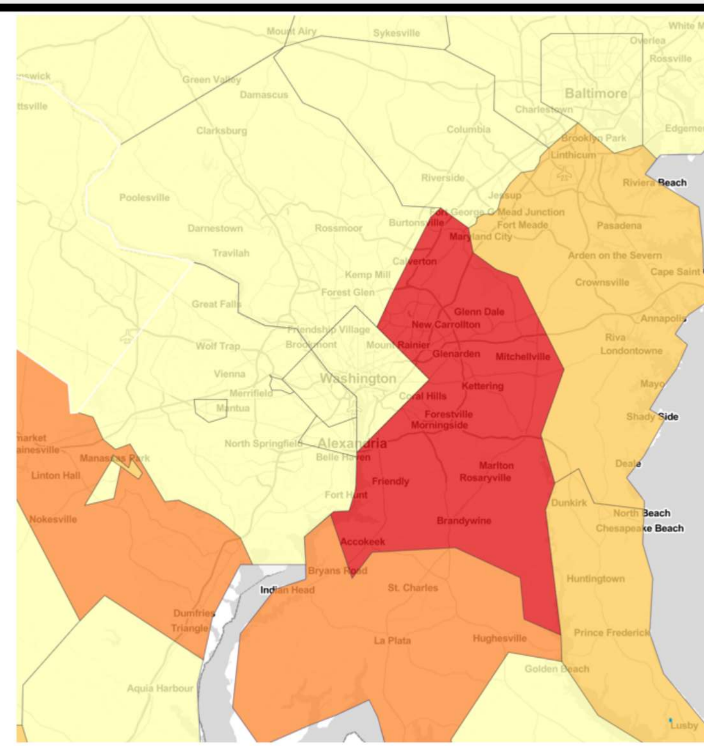
Appendix

SARS-COV-2 Transmission

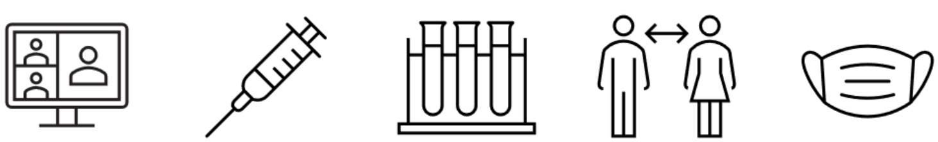
- Presence of infectious individuals or materials
- Inhalation of infectious particles
- Introduction of fomites to mucus membranes

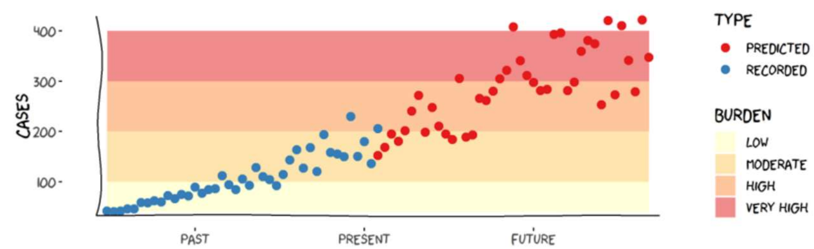
Model layers





Probability of Infection Modifiers





- External Transmission
- Environmental Transmission
- Direct Contact Transmission
- Transmission Modifiers

Environmental Infections Equations

- *Emission Rate*

$$ER_{q,j} = c_v * c_i * IR * \sum_{i=1}^{4}(N_{i,j} * V_i)$$

- *Viral Concentration in Room*

$$n(t) = \frac{ER_q * I}{IVRR * V} + (n_o + \frac{ER_q * I}{IVRR}) * \frac{e^{IVRR*t}}{V}$$

- *Risk of Infection*

$$R_{env} = 1 - e^{-IR \int_0^T n(t)dt}$$

C. Buonanno et al. 2020