▪ Overview of changes in Version 3 and their impacts
▪ Three key scenarios/new model capabilities
  ▪ Stay-at-home order
  ▪ Testing
  ▪ CDC criteria for return (and medical advancement)
▪ Supplemental information
Timeline of Minnesota COVID-19 Model

▪ Version 1: March 2020
  ▪ Based on early data available at the time
▪ Version 2: April 2020
  ▪ Included more specifics about Minnesota cases
▪ Version 3: May 2020
  ▪ Integrates new details and capabilities
▪ Ongoing model updates planned within available capacity
The University of Minnesota and MDH created the Minnesota COVID-19 model as a tool to inform response strategies and resource planning.

Updated model documentation is available online at [Minnesota COVID-19 Modeling](https://mn.gov/covid19/data/modeling) including:

- References for parameter values
- Underlying data
- Model equations governing transitions of the population through COVID-19 health states
Why the Need for New Model Versions?

- COVID-19 remains **in early stages** and new evidence is emerging

- Ongoing model updates are needed to:
  - Reflect the **growing understanding** of COVID-19 transmission and outcomes
  - Incorporate newly emerging **data from the U.S. and Minnesota**
  - Refine projections by fitting model **Minnesota data on observed mortality and hospitalization data**
  - Add **new model capabilities** to illustrate potential mitigation strategies
Data Considerations

- Epidemic and evidence **still very new**
- Extent and impact of **key metrics** uncertain
- Evolving **clinical protocols** with halting dissemination of evidence
- **U.S. case data are limited and incomplete**, affecting availability of robust estimates
Limited U.S. data

- First studies with U.S. patients in late March and April
  - 4,226 cases in U.S. study: outcomes (illness & death) were unknown for 2,001
  - 5,700 patients hospitalized with COVID-19 in NYC area: discharge or death status was known for only 46%
  - Among hospitalized Minnesota COVID-19 patients: nearly 32% remain in the hospital
Five Key Changes to Model Version 3

1. Structural changes to address
   - **Asymptomatic** infections
   - Deaths occurring **outside of hospital**

2. Restricted ICU metric to **ventilated cases**

3. Updated parameter estimates using **newly available US data**
4. Estimate uncertain parameters through model calibration, including

- Proportion of 70+ year-olds dying in non-hospital settings
- Reduction in contacts under social distancing and under stay-at-home order

5. Fitted model to Minnesota deaths and hospitalizations through April 25
**What?**

- **Less time** to epidemic peak
- Some **upward movement** in estimated total mortality

**Why?**

- Calibration to **rising MN deaths**
- **Mitigation less effective** than assumed for:
  - Initial physical distancing (37.6%, not 50%)
  - Stay-at-home order (55.1%, not 80%)
- Changes to **ICU mortality** assumptions & data

Estimates of mitigation effectiveness corrected from presentation on May 13.
### Model Changes: “Stay-at-Home Order in Place for 6 Weeks”

<table>
<thead>
<tr>
<th>Scenario 4*</th>
<th>V 2.0 (incl. uncertainty)</th>
<th>V 3.0 (incl. uncertainty)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weeks until peak</td>
<td>16 (13 to 21)</td>
<td>13 (11 to 13)</td>
</tr>
<tr>
<td>Weeks until ICU capacity reached</td>
<td>16 (13 to 21)</td>
<td>13 (12 to 13)</td>
</tr>
<tr>
<td>Top ICU (ventilator) demand</td>
<td>3,700 (2,700 to 4,900)</td>
<td>3,600 (2,000 to 5,200)§</td>
</tr>
<tr>
<td>Mortality (cumulative for 12 months)</td>
<td>21,800 (9,900 to 36,000)</td>
<td>29,000 (16,000 to 44,000)</td>
</tr>
<tr>
<td>Mortality (through end of May)</td>
<td>N/A</td>
<td>1,700 (1,400 to 2,000)</td>
</tr>
</tbody>
</table>

*Stay-at-Home order in place for a total of 6 weeks (through: May 8, 2020), followed by physical distancing and longer-term stay-at-home recommendation for most vulnerable; § Assuming no ICU capacity constraints
Scenarios & Model Capabilities: An Illustration of Trade-offs
▪ Model-derived estimates:
  ▪ $R_t$ (April 11 through April 25): 1.88
  ▪ Cumulative detection rate: 5.15 percent
  ▪ Percent ever infected: 4.84 percent

▪ Estimates from case counts:
  ▪ Doubling rate: 19.9 days
  ▪ Community transmission (no known contact): 30.8%

Doubling rate is three-day moving average. Full reporting has five- to seven-day data lag. Community transmission among cases with exposure determined through case interviews; it represents a seven-day average.
Unmitigated and Extended Stay-at-Home Orders

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Date of peak infection</th>
<th>Top ICU/vent demand</th>
<th>Mortality (full year)</th>
<th>Mortality (thru May)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 1 Unmitigated (blue)</td>
<td>May 11</td>
<td>4,991</td>
<td>57,035</td>
<td>42,032</td>
</tr>
<tr>
<td>Scenario 5 SHO till 5/18 (red)</td>
<td>June 29</td>
<td>3,397</td>
<td>29,030</td>
<td>1,441</td>
</tr>
<tr>
<td>Scenario 6 SHO till 5/31 (green)</td>
<td>July 6</td>
<td>3,006</td>
<td>28,231</td>
<td>1,388</td>
</tr>
</tbody>
</table>

Stay-at-home order followed by three weeks physical distancing (reduction of contacts by 37.6%) and ongoing stay-at-home recommendation for most vulnerable (50%).
Extended Stay-at-Home Orders & Testing

### Extended Stay-at-Home Orders & Testing

**Scenario 6**
- SHO till 5/31 (green)

**Scenario 5a**
- Worst testg: 70% sens
- 10k tests (orange)

**Scenario 6b**
- Best testg: 95% sens
- 20k tests (purple)

<table>
<thead>
<tr>
<th></th>
<th>Scenario 6</th>
<th>Scenario 5a</th>
<th>Scenario 6b</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Date of peak infection</strong></td>
<td>July 6</td>
<td>June 29</td>
<td>July 13</td>
</tr>
<tr>
<td><strong>Top ICU/vent demand</strong></td>
<td>3,006</td>
<td>3,150</td>
<td>2,444</td>
</tr>
<tr>
<td><strong>Mortality (full year)</strong></td>
<td>28,231</td>
<td>26,914</td>
<td>22,589</td>
</tr>
<tr>
<td><strong>Mortality (thru May)</strong></td>
<td>1,388</td>
<td>1,430</td>
<td>1,375</td>
</tr>
</tbody>
</table>

At this point the impact of testing applies only to tested individual by reducing their rate of contact (assuming isolation for confirmed positive cases); tests are distributed to “I” states and non-“I” states, through probabilities of testing access. Reduced contact through contact tracing is currently not built into the model.
Extended Stay-at-Home Order, CDC Guidelines for “Opening Up” and Medical Advancement

### Scenarios Overview

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Date of peak infection</th>
<th>Top ICU/vent demand</th>
<th>Mortality (full year)</th>
<th>Mortality (thru May)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 SHO till 5/31 (green)</td>
<td>July 6</td>
<td>3,006</td>
<td>28,231</td>
<td>1,388</td>
</tr>
<tr>
<td>7 CDC Opening (aqua)</td>
<td>July 6</td>
<td>1,034</td>
<td>26,294</td>
<td>1,388</td>
</tr>
<tr>
<td>8 CDC Opening + Tx (pink)</td>
<td>July 6</td>
<td>1,034</td>
<td>25,392</td>
<td>1,388</td>
</tr>
</tbody>
</table>


Rx treatment (Tx) only for hospitalized patients, 30% reduction in LOS & mortality
Daily Deaths – All Scenarios

Scenarios:
- 1
- 5
- 5a
- 6
- 6b
- 7
- 8
Cumulative Infections – All Scenarios
Uncertainty Estimates for Key Model Outcomes
Consideration for Next Steps

- More and better data from U.S. epidemic
- Refined scenarios
  - Treatment: evidence on home treatment
  - Testing: incorporate impact of contact tracing
- Enhancements: cycling mitigation
Team Acknowledgement

UMN
- Marina Kirkeide
- Gregory Knowlton
- Abhinav Mehta
- Richard MacLehose
- Kumi Smith
- Kelly Searle
- Ran Zhao
- Katherine Harripersaud
- Sara Lammert

MDH
- Pam Mink
- Alisha Simon
- Erinn Sanstead
- Plus a large team of epidemiologists

We also wish to thank a number of anonymous reviewers of the programming code, the underlying methodology and data, as well as peers across the country whose expertise benefited this work on behalf of Minnesotans.
## Scenarios with Uncertainty Estimates

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Unmitigated</th>
<th>Stay-at-home until 5/18</th>
<th>Stay-at-home until 6/1</th>
<th>Stay-at-home until 5/31 – 20k tests per day, 95% sens</th>
<th>Stay-at-home until 5/18, 10k tests per day/75% sens</th>
<th>CDC reopening strategy</th>
<th>CDC reopening strategy + medical advancement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weeks until Peak (range)</td>
<td>7 (6 to 7)</td>
<td>14 (13 to 14)</td>
<td>15 (14 to 16)</td>
<td>16 (15 to 17)</td>
<td>14 (13 to 15)</td>
<td>15 (13 to 26)</td>
<td>15 (13 to 26)</td>
</tr>
<tr>
<td>Weeks until ICU capacity reached (range)</td>
<td>4 (4 to 4)</td>
<td>14 (13 to 15)</td>
<td>15 (14 to 16)</td>
<td>17 (16 to 18)</td>
<td>14 (13 to 15)</td>
<td>Does not reach capacity (24 to 27)</td>
<td>Does not reach capacity (25 to 26)</td>
</tr>
<tr>
<td>Top ICU Demand (range)</td>
<td>4,991 (2,761 to 6,928)</td>
<td>3,397 (1,875 to 5,039)</td>
<td>3,006 (1,577 to 4,739)</td>
<td>2,444 (1,223 to 3,667)</td>
<td>3,150 (1,719 to 4,644)</td>
<td>1,034 (547 to 2,520)</td>
<td>1,034 (480 to 1,822)</td>
</tr>
<tr>
<td>Mortality – 1 year (range)</td>
<td>57,035 (31,036 to 79,580)</td>
<td>29,030 (15,726 to 43,868)</td>
<td>28,231 (15,834 to 43,152)</td>
<td>22,589 (12,903 to 32,012)</td>
<td>26,914 (14,804 to 40,608)</td>
<td>26,294 (14,617 to 37,269)</td>
<td>25,392 (14,044 to 35,179)</td>
</tr>
<tr>
<td>Mortality – end of May (range)</td>
<td>42,032 (24,736 to 53,908)</td>
<td>1,441 (1,082 to 1,554)</td>
<td>1,388 (988 to 1,494)</td>
<td>1,375 (980 to 1,481)</td>
<td>1,430 (1,069 to 1,543)</td>
<td>1,388 (988 to 1,494)</td>
<td>1,388 (988 to 1,494)</td>
</tr>
<tr>
<td>Percentage of population infected – 1 year (range)</td>
<td>87.5% (87.4% to 87.5%)</td>
<td>79.4% (79.0% to 80.4%)</td>
<td>78.7% (77.9% to 80.3%)</td>
<td>73.3% (70.8% to 75.7%)</td>
<td>77.8% (77.1% to 78.9%)</td>
<td>71.0% (69.3% to 76.5%)</td>
<td>71.0% (69.3% to 76.5%)</td>
</tr>
</tbody>
</table>
## Input Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>V1</th>
<th>V2</th>
<th>V3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unmitigated basic reproduction number (R0)</td>
<td>2.38</td>
<td>3.87</td>
<td>3.87</td>
</tr>
<tr>
<td>Transmission probability (per contact between infected/susceptible persons)</td>
<td>0.009¶</td>
<td>0.035*</td>
<td>0.0295*</td>
</tr>
<tr>
<td>Latent period</td>
<td>5 days</td>
<td>5 days</td>
<td>5.2 days</td>
</tr>
<tr>
<td>Infectious period</td>
<td>8 days</td>
<td>8 days</td>
<td>7.8 days</td>
</tr>
<tr>
<td>ICU duration</td>
<td>22.6 days</td>
<td>10.3 days</td>
<td>8 days</td>
</tr>
<tr>
<td>Hospitalization duration</td>
<td>8 days</td>
<td>13.3 days</td>
<td>11 days</td>
</tr>
<tr>
<td>Increased mortality factor with ≥ 1 comorbidity</td>
<td>7.6</td>
<td>7.6</td>
<td>1.0 (not used)</td>
</tr>
<tr>
<td>Increased mortality factor if ICU capacity exceeded</td>
<td>1.5 to 16.5</td>
<td>1.5 to 16.5</td>
<td>Assume death</td>
</tr>
<tr>
<td>Hospitalized cases requiring ICU (age ranges)</td>
<td>5.0% to 70.9%</td>
<td>5.0% to 70.9%</td>
<td>11.9% to 29.6%*</td>
</tr>
<tr>
<td>ICU mortality rate (age ranges)</td>
<td>0.000 to 0.111</td>
<td>0.000 to 0.111</td>
<td>0.0005 to 0.779§</td>
</tr>
</tbody>
</table>

¶ Corresponds to an R0 of 2.38; *Corresponds to an R0 of 3.87; * Restricted to ventilated cases
§ Probability of dying
### Model Parameters Estimated Through Calibration

<table>
<thead>
<tr>
<th>Parameter</th>
<th>V1</th>
<th>V2</th>
<th>V3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proportion of cases detected prior to start of model simulation*</td>
<td>0.119 (input)</td>
<td>0.01</td>
<td>0.021</td>
</tr>
<tr>
<td>Hospitalized infections (age ranges)</td>
<td>0.1% to 27.3%</td>
<td>0.1% to 27.3%</td>
<td>10.3%**</td>
</tr>
<tr>
<td>Proportion of people aged 70 or older with a symptomatic infection die at home</td>
<td>N/A</td>
<td>N/A</td>
<td>0.139</td>
</tr>
<tr>
<td>Proportion of infections which are mild or asymptomatic</td>
<td>0.0 (input)</td>
<td>0.25 (input)</td>
<td>0.41</td>
</tr>
<tr>
<td>Estimated contact reduction caused by the social distancing</td>
<td>0.5 (input)</td>
<td>0.5 (input)</td>
<td>37.6%</td>
</tr>
<tr>
<td>Estimated contact reduction caused by the stay-at-home order</td>
<td>0.8 (input)</td>
<td>0.8 (input)</td>
<td>55.1%</td>
</tr>
</tbody>
</table>

*Case detection rate only used for model initialization

**Calculate age-specific hospitalization probabilities, prop hosp, the relative proportion of symptomatic cases by age is multiplied by the calibrated values for the probability of 80+ year-olds who are hospitalized.
Uncertainty - Percentage Cumulative Infections

The graph illustrates the percentage cumulative infections over time for different scenarios. The x-axis represents time in days, ranging from 0 to 300, while the y-axis shows the percentage cumulative infections, ranging from 0 to 100.

The scenarios are represented by different colors: blue for Scenario 1, yellow for Scenario 5a, and magenta for Scenario 8.
Uncertainty – Prevalent Hospitalizations
Uncertainty – Prevalent Infections
Uncertainty – Daily Deaths