# COVID-19 Modeling for Virginia

## Presentation for VDOE

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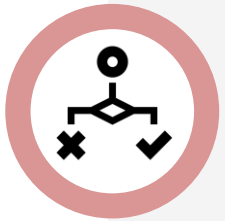
RAND CORPORATION HEALTH CARE

# VIRGINIA COVID-19 MODELS

Carter C. Price, Ph.D.

# What constitutes a suitable model?

We won't know how accurate a model is until after the fact



Models should behave in explainable ways

- Policy changes should produce results that move in the direction we expect
- The magnitude of the response to these changes should be based on data and analysis

Resource constraints are real but there is an asymmetric risk with modeling COVID-19

- One too many ICU beds or ventilators costs a few thousand dollars; one too few costs lives
- Assumptions and biases should reflect this concern

# Model types

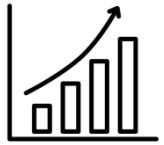
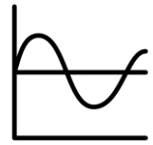
## Statistical Models

- IHME model
- Projections based on curves that are fitted to historical data
- Include other factors as controls, such as policy responses

## Systems Dynamics Models

- UVA model and CHIME model
- Assume exponential growth in the number infected
- Rely on estimates of the rate of spread

# Advantages of modeling approaches

| Type of Model | Systems Dynamics | Statistical | Alternative |
|---|---|---|---|
| Example | UVA and CHIME | IHME | VDH |
| Degree of a Threat | | | Surveillance |
| Rate of Spread | | | Surveillance |
| Extent of Spread | | | Experts |
| Timing of the Peak | | | Experts |
| Severity | | | Experts |

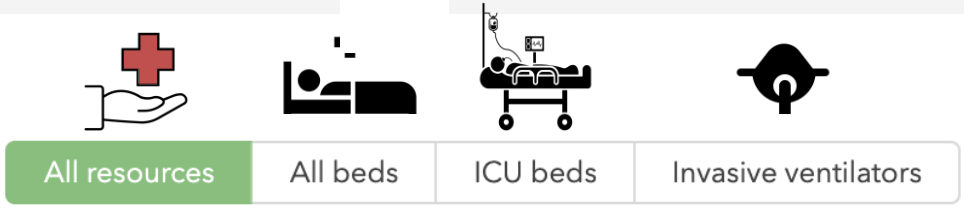
Highly Suitable
Suitable
Somewhat suitable
Not Suitable

Derived from: Manheim, David, Margaret Chamberlin, Osonde A. Osoba, Raffaele Vardavas, and Melinda Moore, Improving Decision Support for Infectious Disease Prevention and Control: Aligning Models and Other Tools with Policymakers' Needs. Santa Monica, CA: RAND Corporation, 2016. https://www.rand.org/pubs/research_reports/RR1576.html.

# University of Washington's IHME Model

**IHME fits a statistical model for the trajectory of confirmed COVID-19 deaths and then projects it forward**

- Hospitalization rates and the utilization of both ICU beds and ventilators are estimated using a simulation based on the estimated death rate
- Based on data not just from Virginia, but also China, Italy, Washington State, and other areas




**This is not an SIR/SEIR-model and will behave independently from those**

This model provides a different perspective from the other types of models

**The model is likely biased though it should improve with more and better data**

- Model results are not stable—the difference between the current and previous runs differ by 25% for VA
- Because of the lack of testing, many COVID-19 deaths may not be confirmed, which could bias the trends
- Policy interventions are treated equally (i.e., how many recommended policies does the locale implement?)

# Penn Medicine's CHIME Model

- CHIME is a Systems Dynamics Model where people transition between Susceptible, Infected, and Recovered (SIR)
  - The population starts in the susceptible state, the infection spreads exponentially, and people recover (or die) at a defined rate
  - Hospital bed and ICU bed utilization are based on fixed ratios

- Each infected person is modeled as infecting some number of people (based on the rate) on average
  - Conceptually, these methods reflect a realistic spread for the early- to middle phase of an epidemic
  - Easy to implement and fast to run

- Because they are simple, there are only a few ways to model policy responses
  - See the case of social distancing

# UVA Model

- Biocomplexity Institute at the University of Virginia
  - Using big data and simulations to understand massively interactive systems
- Over 20 years of crafting and analyzing infectious disease models
  - Pandemic response and support for Influenza, Ebola, Zika, others

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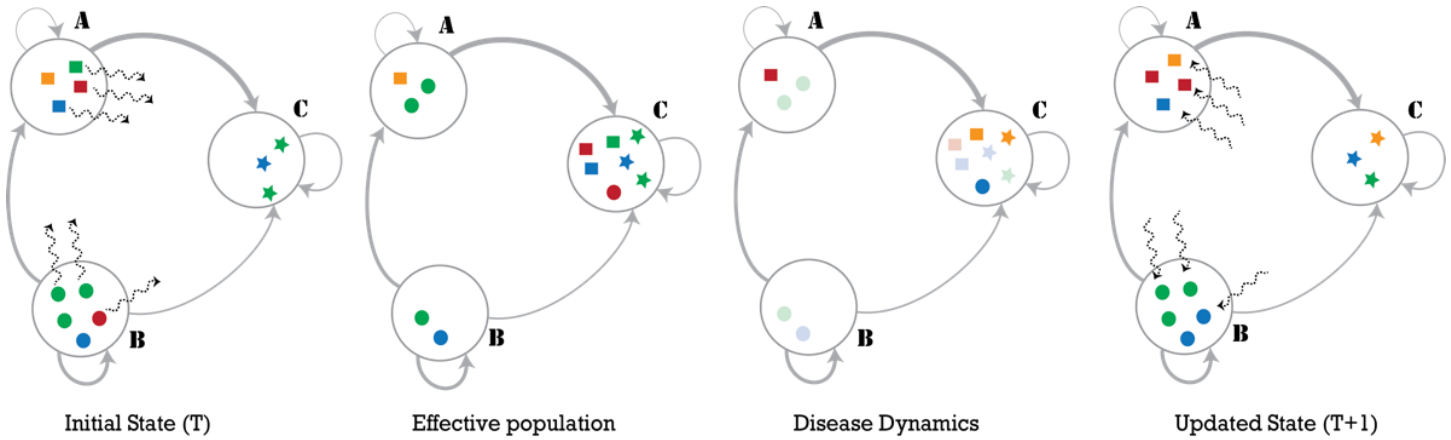
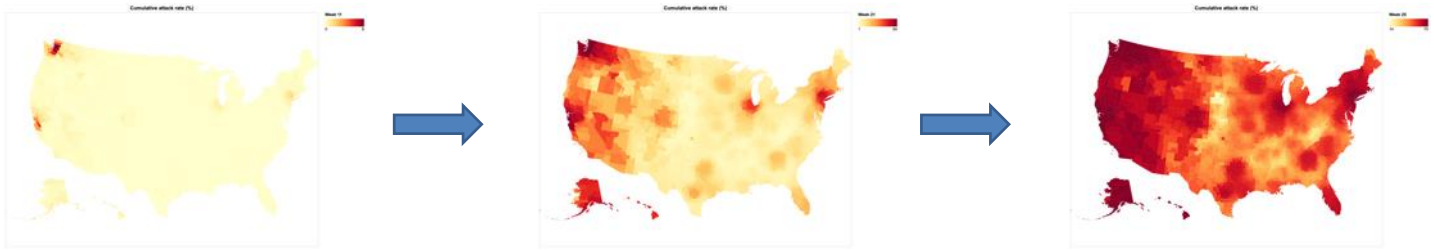
Executive Director

**Madhav Marathe**
Division Director

# UVA Model: Simulation Engine – PatchSim

- Metapopulation model
  - Represents each population and its interactions as a single patch
  - 133 patches for Virginia counties and independent cities
- Extended SEIR disease representation
  - Includes asymptomatic infections and treatments
- Mitigations affect both disease dynamics and population interactions
- Runs fast on high-performance computers
  - Ideal for calibration and optimization



Venkatramanan, Srinivasan, et al. "Optimizing spatial allocation of seasonal influenza vaccine under temporal constraints." *PLoS Computational Biology* 15.9 (2019): e1007111.

# UVA Model: Full Parameters

| Parameter | Estimated Values | Description [Source] |
|---|---|---|
| Transmissibility (R0) | 2.2 [2.1 – 2.3] | Reproductive number * |
| Incubation period | 5 days | Time from infection to Infectious * |
| Infectious period | 3.3 - 5 days | Duration of infectiousness * |
| Proportion asymptomatic | 50% | Proportion of infections that don't exhibit symptoms * |
| Proportion hospitalized | 5.5% (~20% of confirmed) | Symptomatic Infections becoming Hospitalized * |
| Proportion in ICU | 20% | Hospitalized patients that require ICU * |
| Proportion ventilated | 70% | Proportion of ICU requiring ventilation * |
| Onset to hospitalization | 5 days | Time from symptoms to hospitalization * |
| Hospitalization to ventilation | 3 days | Time from hospitalization to ventilation * |
| Duration hospitalized | 10 days | Time spent in the hospital |
| Duration ventilated | 14 days | Time spent on a ventilator † |
| Infection detection rate | 15% | One confirmed case becomes ~7 initial infections # |

* CDC COVID-19 Modeling Team. "Best Guess" scenario. Planning Parameters for COVID-19 Outbreak Scenarios. Version: 2020-03-31.
† Up-to-date. COVID-19 Critical Care Issues. https://www.uptodate.com/contents/coronavirus-disease-2019-covid-19-critical-care-issues?source=related_link
# Li et al., *Science* 16 Mar 2020:eabb3221 https://science.sciencemag.org/content/early/2020/03/24/science.abb3221

# UVA Model: Mitigation Scenarios

- **Consider 5 possible futures:** Two levels of intensity with two durations and one with no effect
- **Start of social distancing:** March 15th, as measured from VDH data
- **Duration:** Lift on April 30th or lift on June 10th

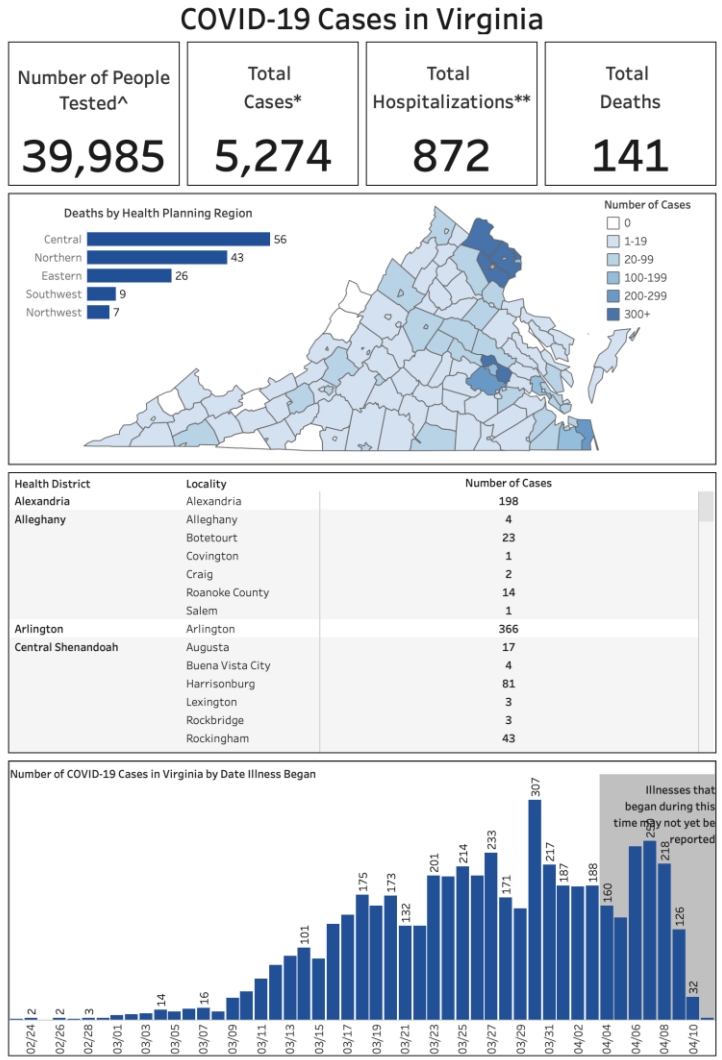
- **Intensity of mitigation:**

  Slowing growth vs. Pausing growth
  - **Slowing –** Social distancing slows the growth, but new cases do increase
  - **Pausing –** Social distancing pauses growth, keeping new cases steady
  - Pausing scenarios track the data better

| Duration (lift date) | Intensity | Short Name | Description |
|---|---|---|---|
| Apr 30th | Slowing | Slow - Apr30 | Slowing intensity, lift April 30th |
| June 10th | Slowing | Slow - Jun10 | Slowing intensity, lift June 10th |
| Apr 30th | Pausing | Pause – Apr30 | Pausing intensity, lift April 30th |
| June 10th | Pausing | Pause – Jun10 | Pausing intensity, lift June 10th |
| None | Unmitigated | Unmitigated | No effect of social distancing |

# UVA Model: Calibration Approach

- **Data:**
  - County level case counts by date of onset (from VDH)
  - Confirmed cases for model fitting
- **Calibration:** Fit model to observed data
  - Search transmissibility and duration of infectiousness
  - Markov Chain Monte Carlo (MCMC) particle filtering finds best fits while capturing uncertainty in parameter estimates
- **Projections:** Future cases and outcomes using the trained particles

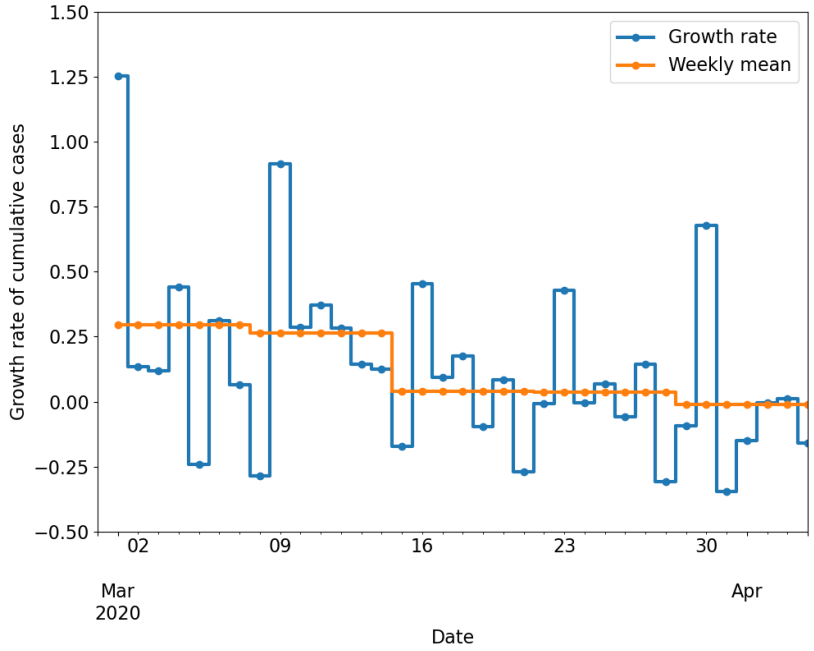



Accessed 1pm April 12, 2020

https://public.tableau.com/views/VirginiaCOVID-19Dashboard/VirginiaCOVID-19Dashboard

# UVA Model:
# Estimating Effects of Social Distancing

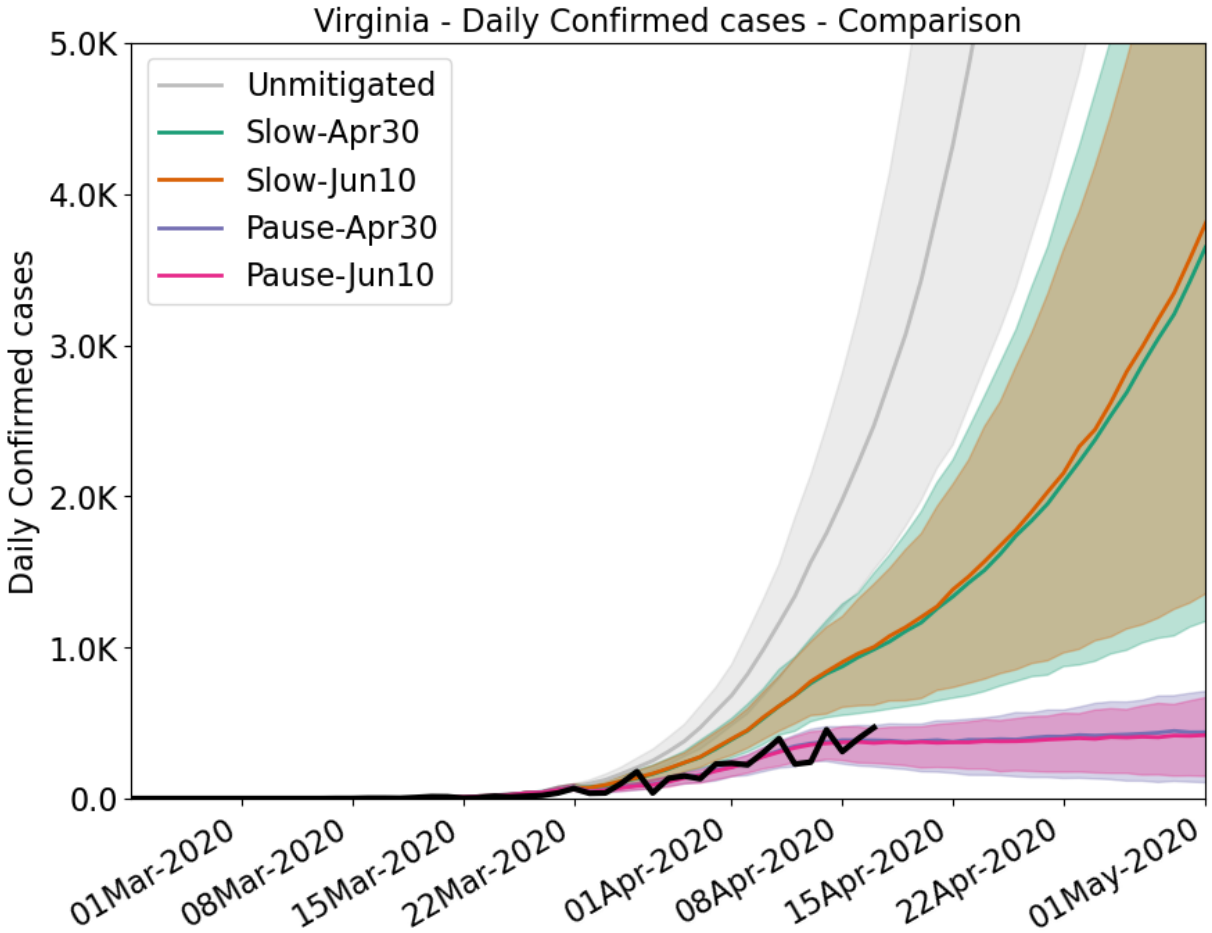
- **Anonymized mobility data shows Virginia greatly reduced activities**
  - Google: -44% retail & recreation, -18% grocery stores, -39% workplaces
  - Cuebiq: >50% reduction of average individual mobility compared to Year Avg.
- **VDH data shows reductions in growth rate starting in mid-March**
  - Weekly average growth rate by date of onset
    - Week before March 15 = 0.3
    - Week after March 15 = 0.03
  - Equivalent reproductive number change
    - 2.2 before March 15th
    - 1.1 after March 15th

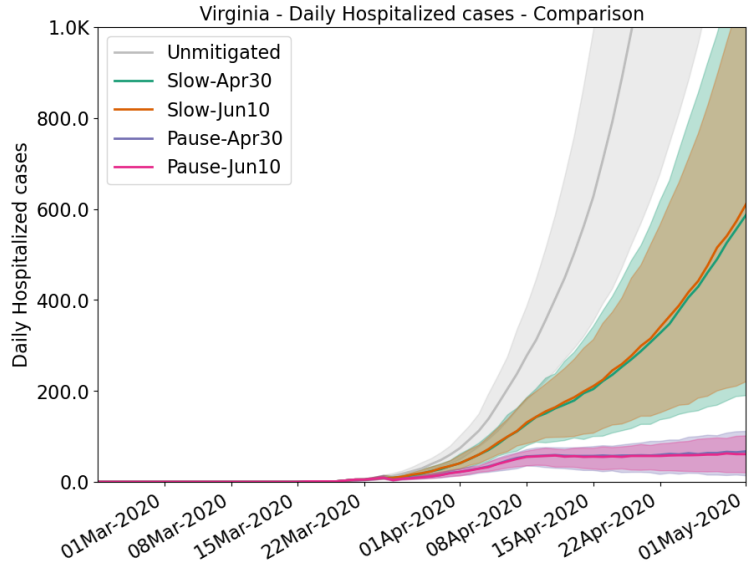


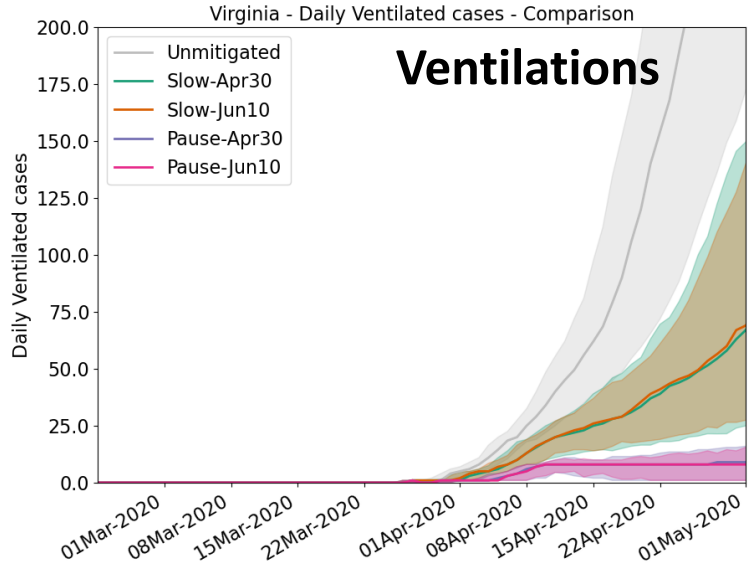

Google. COVID-19 community mobility reports. https://www.google.com/covid19/mobility/
Cuebiq: COVID-19 Mobility insights. https://www.cuebiq.com/visitation-insights-covid19/

# UVA Model: Short-term Projections

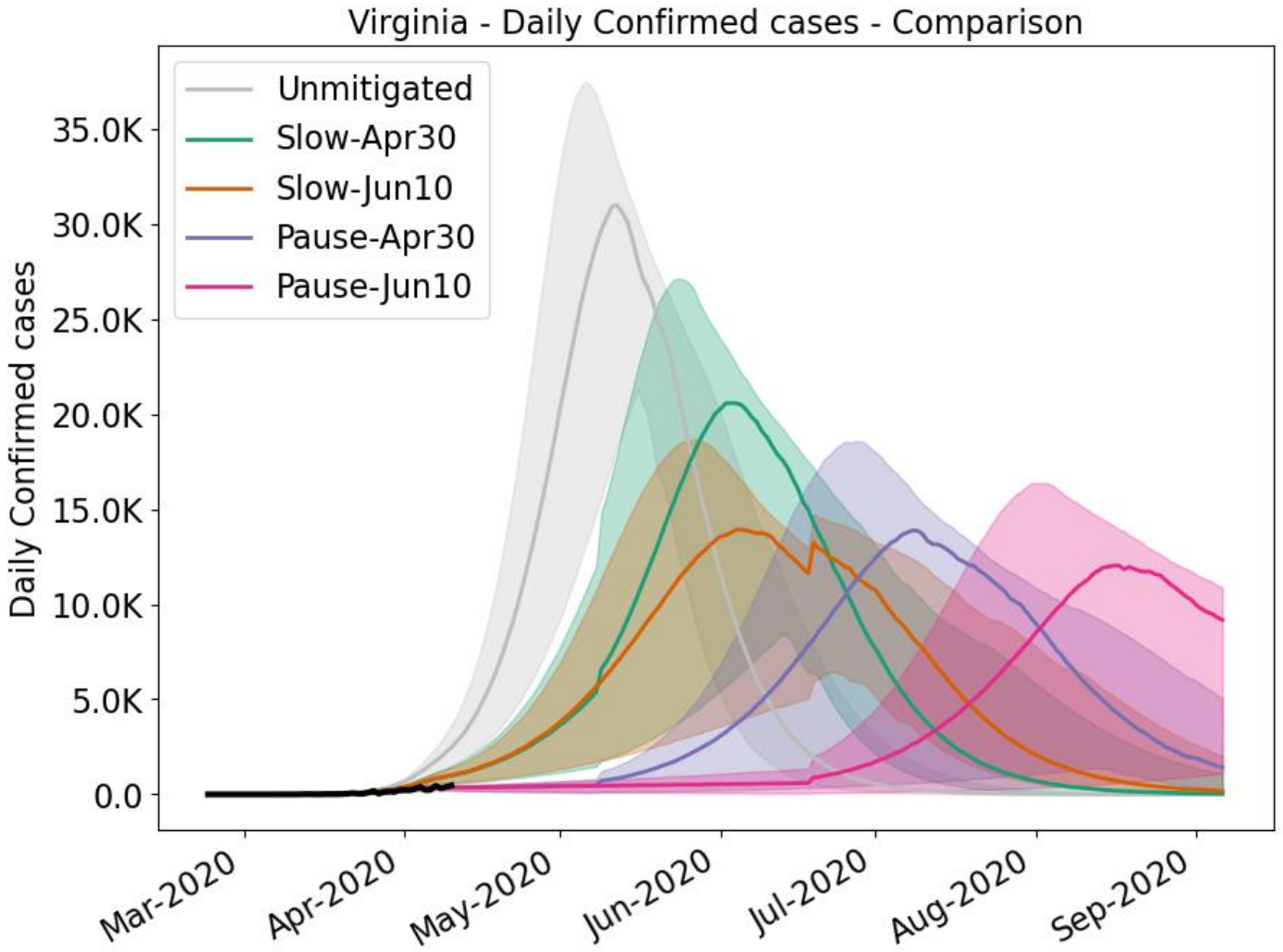
## Confirmed cases



# UVA Model:
# Stay the Course: Future Depends on Policy



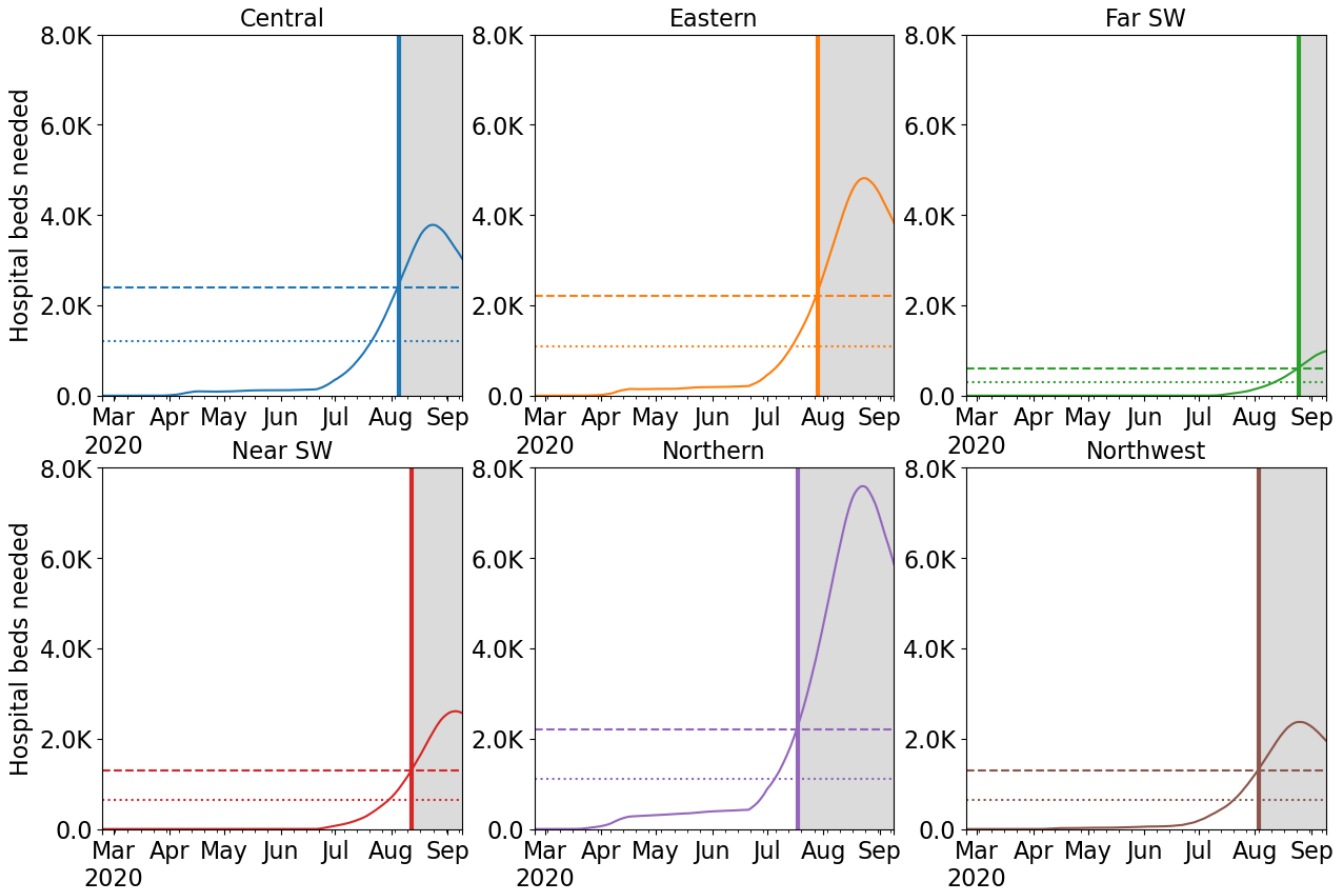

**Weekly New Confirmed Cases**

| Week ending | Unmitigated | Slow Jun10 | Pause Jun10 |
|---|---|---|---|
| 4/12/20 | 11,846 | 5,518 | 2,469 |
| 4/19/20 | 25,712 | 8,502 | 2,599 |
| 4/26/20 | 53,562 | 13,076 | 2,742 |
| 5/3/20 | 101,876 | 19,881 | 2,944 |
| 5/10/20 | 164,527 | 29,567 | 3,151 |
| 5/17/20 | 200,184 | 42,312 | 3,345 |
| 5/24/20 | 182,818 | 57,679 | 3,558 |
| 5/31/20 | 136,652 | 73,380 | 3,770 |
| 6/7/20 | 84,016 | 85,874 | 3,962 |
| 6/14/20 | 46,350 | 89,390 | 4,144 |
| 6/21/20 | 23,363 | 85,226 | 4,470 |
| 6/28/20 | 11,366 | 91,648 | 7,850 |

Numbers are medians of projections

# UVA Model:
# Hospital Demand and Capacity by Region

**Capacities by Region – Pause June 10**




Assumes average length of stay of 10 days

COVID-19 capacity ranges from 80% (dots) to 120% (dash) of total beds

**Date ranges when regions are estimated to exceed surge capacity**

| Scenario | Date Ranges |
|---|---|
| Slow – Apr30 | Early May – Early June |
| Slow – Jun10 | Early May – Mid June |
| Pause – Apr30 | Mid June – Late July |
| Pause – Jun10 | Mid July – Late August |
| Unmitigated | Late April – Mid May |

**Social Distancing postpones the time when capacity is exceeded 1 to 2.5 months**

**Timing estimates can be used for planning to augment existing capacities if needed**

# Comparison of Models

IHME may have the peak too early and the resource requirements too low at the peak because of bias in the data

UVA and IHME models should get more accurate in time as more relevant data become available

- The dearth of initial testing may bias all of the models
- Many of the parameters used in the models come from China studies that might not be as relevant

CHIME is best used as a decision support tool for hospital level utilization rather than as a forecast

A synthesis should produce more suitable results

A composite of the different models can reduce bias and produce more accurate estimates and ranges

# Comparison of UVA and IHME Model Outputs Hospitalizations

| Source | IHME https://covid19.healthdata.org/united-states-of-america/virginia Accessed 4/13/2020 | UVA PatchSim Model on 4/11/2020 Pause Lift April 30th | UVA PatchSim Model on 4/11/2020 Pause Lift June 10th |
|---|---|---|---|
| **Date of Peak** | 4/27 (4/13-5/26) | Early July | Mid August |
| **Date Exceed Bed Capacity** | -- | Mid-June to Late July | Mid-July to Late August |
| **Peak Hospital Census for COVID-19** | 340-4,700 | 17,000-24,000 | 15,000-22,000 |

# UVA Model: Key Takeaways

Projecting future cases precisely is impossible and unnecessary.
Even without perfect projections, we can confidently draw conclusions:

- **Current social distancing efforts are working.**
- Under current conditions, Virginia *as a whole* will have sufficient medical resources for at least the next couple months.
- Lifting social distancing restrictions too soon can lead quickly to a second wave.
- Further modeling could explore the effectiveness of containment strategies (test-isolate-contact tracing-quarantine).
- The situation is changing rapidly. Models will be updated regularly.